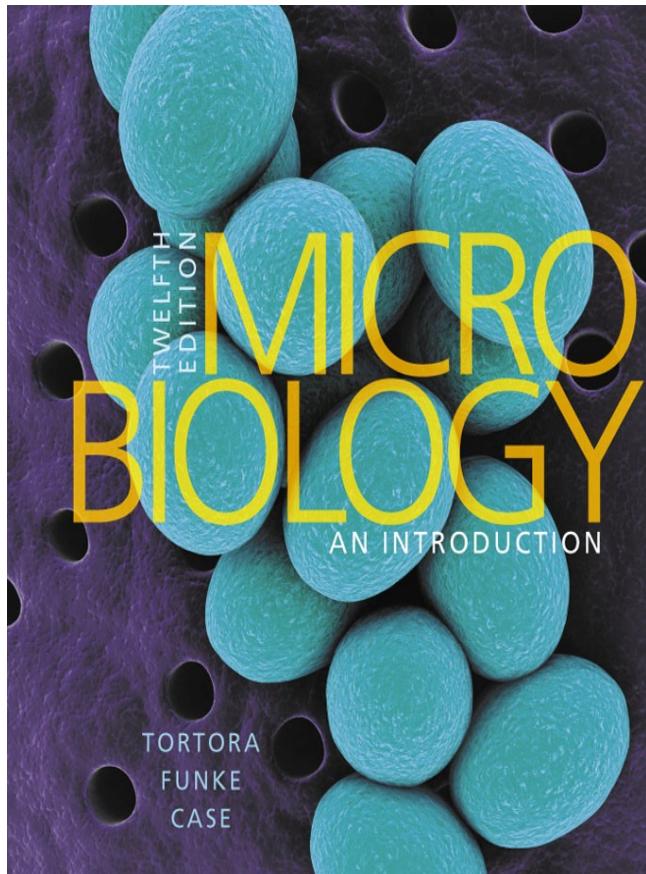


# **Microbiology an Introduction**

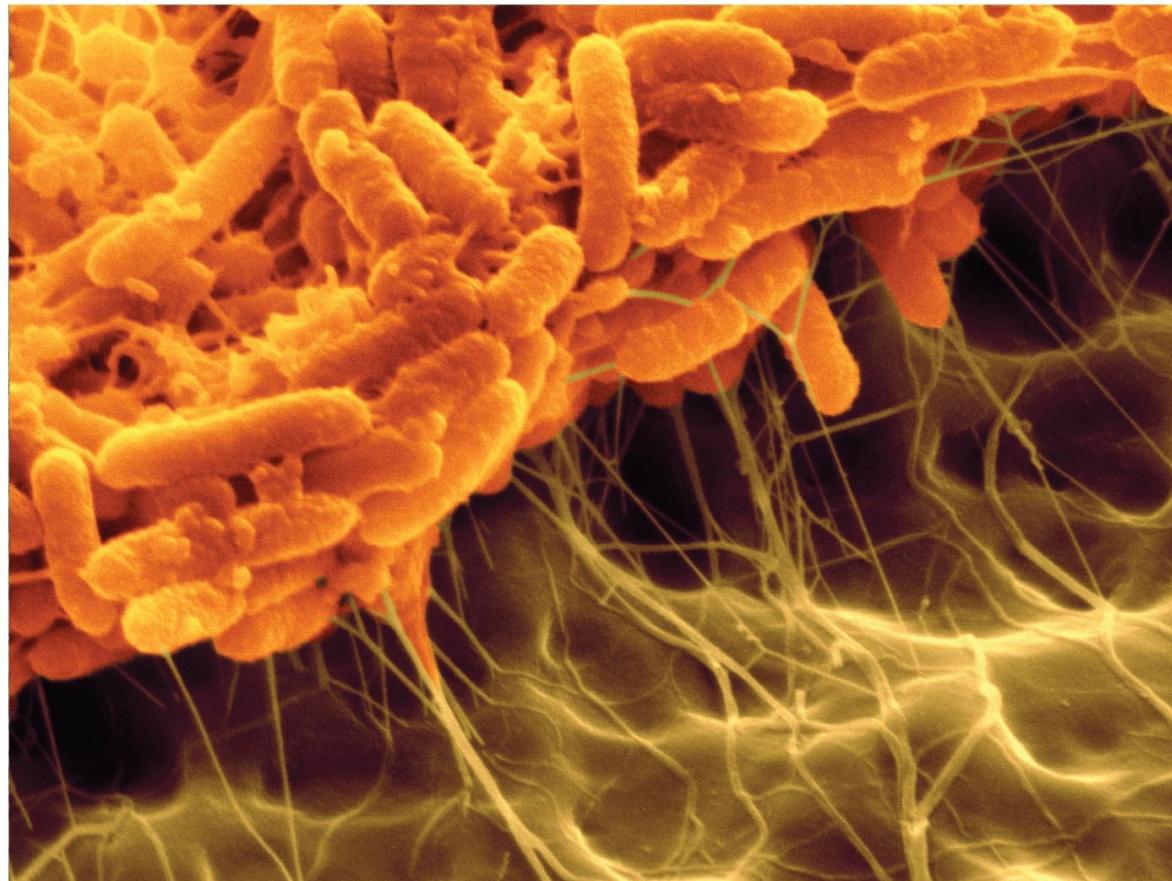
**Twelfth Edition**



## **Chapter 4**

### **Functional Anatomy of Prokaryotic and Eukaryotic Cells**

# Serratia Bacteria



# Comparing Prokaryotic and Eukaryotic Cells: An Overview (1 of 3)

## Learning Objective

4-1 Compare the cell structure of prokaryotes and eukaryotes.

# Comparing Prokaryotic and Eukaryotic Cells: An Overview (2 of 3)

- **Prokaryote** comes from the Greek words for prenucleus.
- **Eukaryote** comes from the Greek words for true nucleus.

# Comparing Prokaryotic and Eukaryotic Cells: An Overview (3 of 3)

## Prokaryote

- One circular chromosome, not in a membrane
- No histones
- No organelles
- Bacteria: peptidoglycan cell walls
- Archaea: pseudomurein cell walls
- Divides by binary fission

## Eukaryote

- Paired chromosomes, in nuclear membrane
- Histones
- Organelles
- Polysaccharide cell walls, when present
- Divides by mitosis

# **Check Your Understanding-1**

## **Check Your Understanding**

- ✓ What is the main feature that distinguishes prokaryotes from eukaryotes?

4-1

# The Prokaryotic Cell

## Learning Objective

4-2 Identify the three basic shapes of bacteria.

# The Size, Shape, and Arrangement of Bacterial Cells

(1 of 4)

- Average size: 0.2 to 2.0  $\mu\text{m}$  diameter  $\times$  2 to 8  $\mu\text{m}$  length
- Most bacteria are monomorphic (single shape)
- A few are pleomorphic (many shapes)

# The Size, Shape, and Arrangement of Bacterial Cells

(2 of 4)

- Bacillus (rod-shaped)
- Coccus (spherical)
- Spiral
  - Vibrio
  - Spirillum
  - Spirochete
- Star-shaped
- Rectangular

# Figure 4.4 Spiral Bacteria



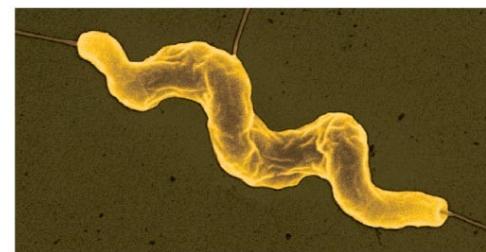
(a) Vibrio



SEM 4  $\mu\text{m}$



(b) Spirillum



SEM 4  $\mu\text{m}$

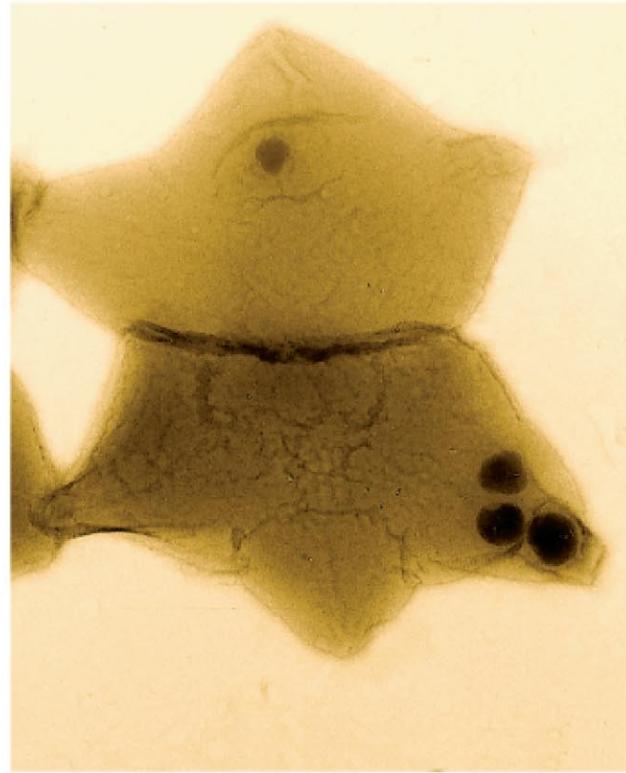
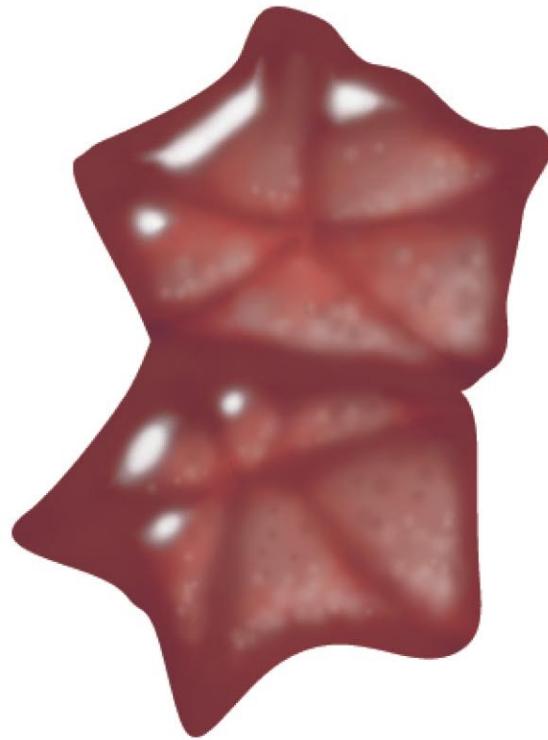


(c) Spirochete



SEM 1  $\mu\text{m}$

# Figure 4.5a Star-Shaped and Rectangular Prokaryotes

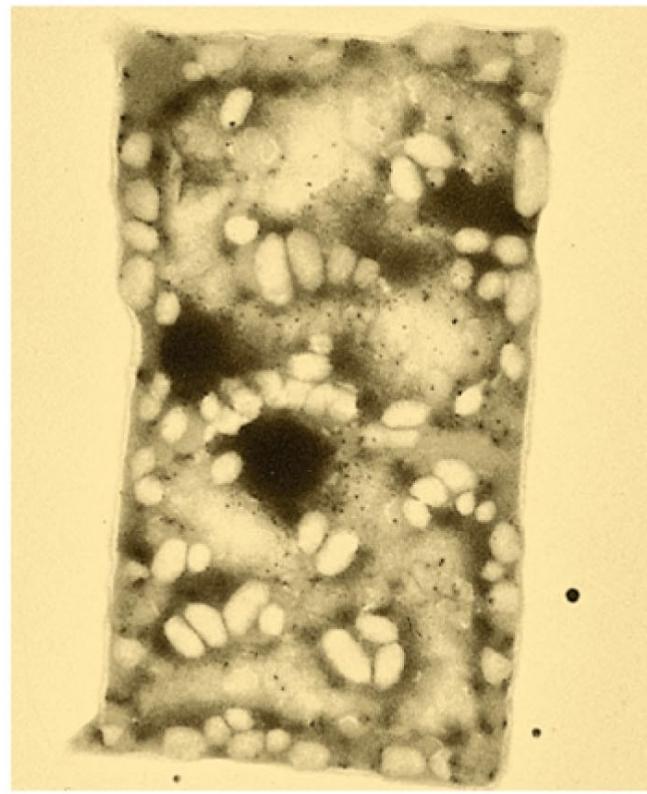


**(a)** Star-shaped bacteria

TEM

0.5  $\mu\text{m}$

# Figure 4.5b Star-Shaped and Rectangular Prokaryotes



**(b)** Rectangular bacteria

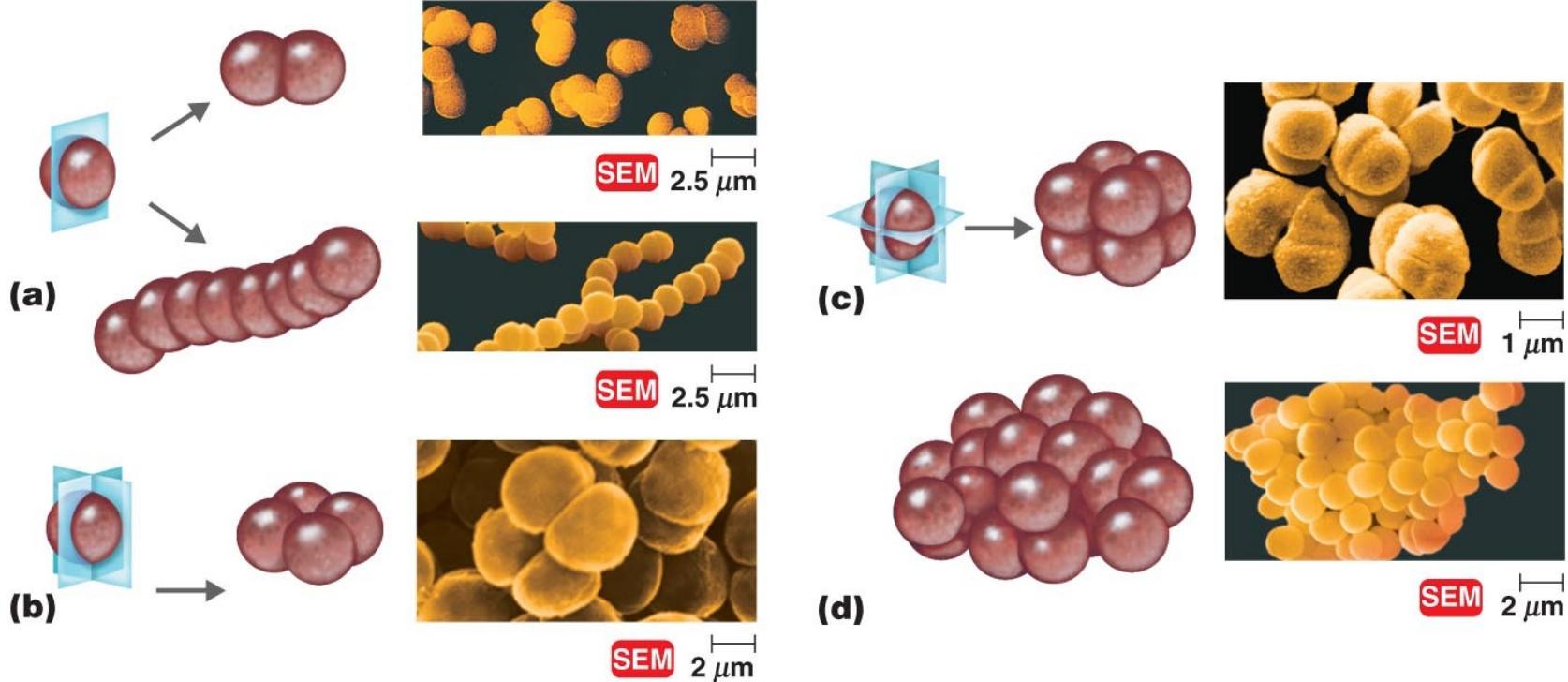
TEM

1  $\mu\text{m}$

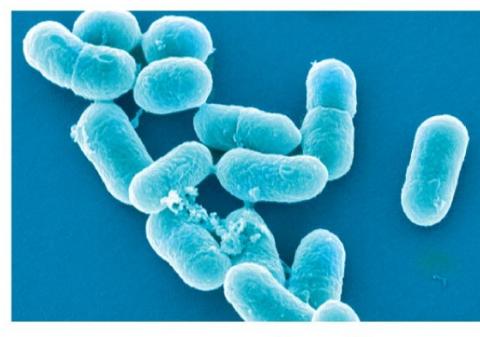
# The Size, Shape, and Arrangement of Bacterial Cells (3 of 4)

- Pairs: **diplococci, diplobacilli**
- Clusters: **staphylococci**
- Chains: **streptococci, streptobacilli**
- Groups of four: **tetrads**
- Cubelike groups of eight: **sarcinae**

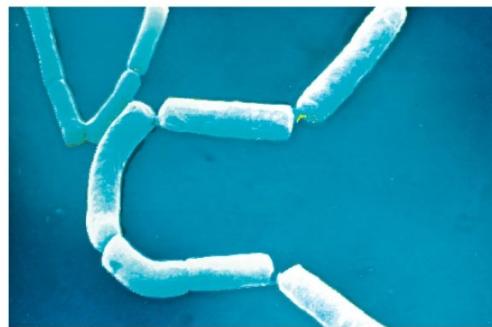
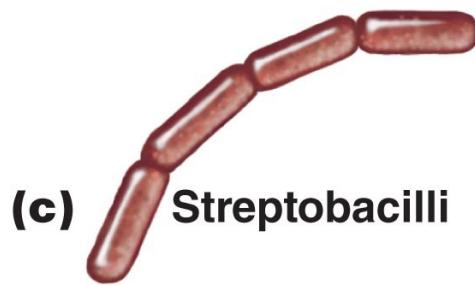
# Figure 4.1 Arrangements of Cocci



# Figure 4.2a-d Bacilli



# Figure 4.2b-c Bacilli

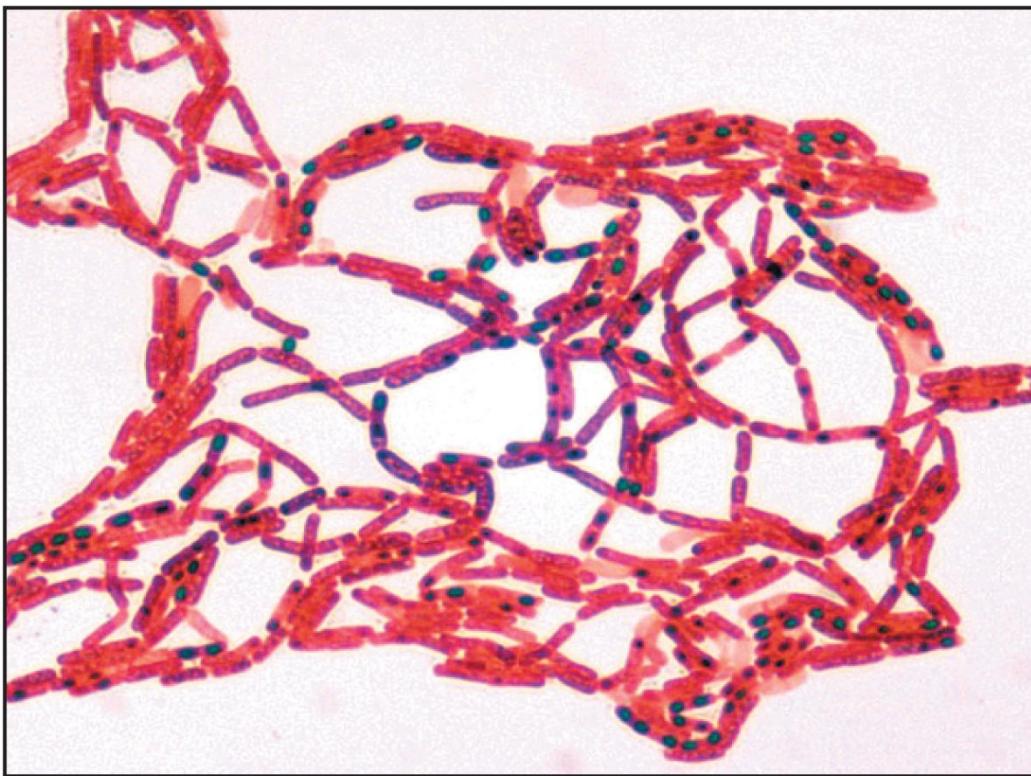


# The Size, Shape, and Arrangement of Bacterial Cells

(4 of 4)

- Scientific name: **Bacillus**
- Shape: bacillus

# Figure 4.3 Gram-Stained *Bacillus Anthracis*



LM      | 15  $\mu\text{m}$

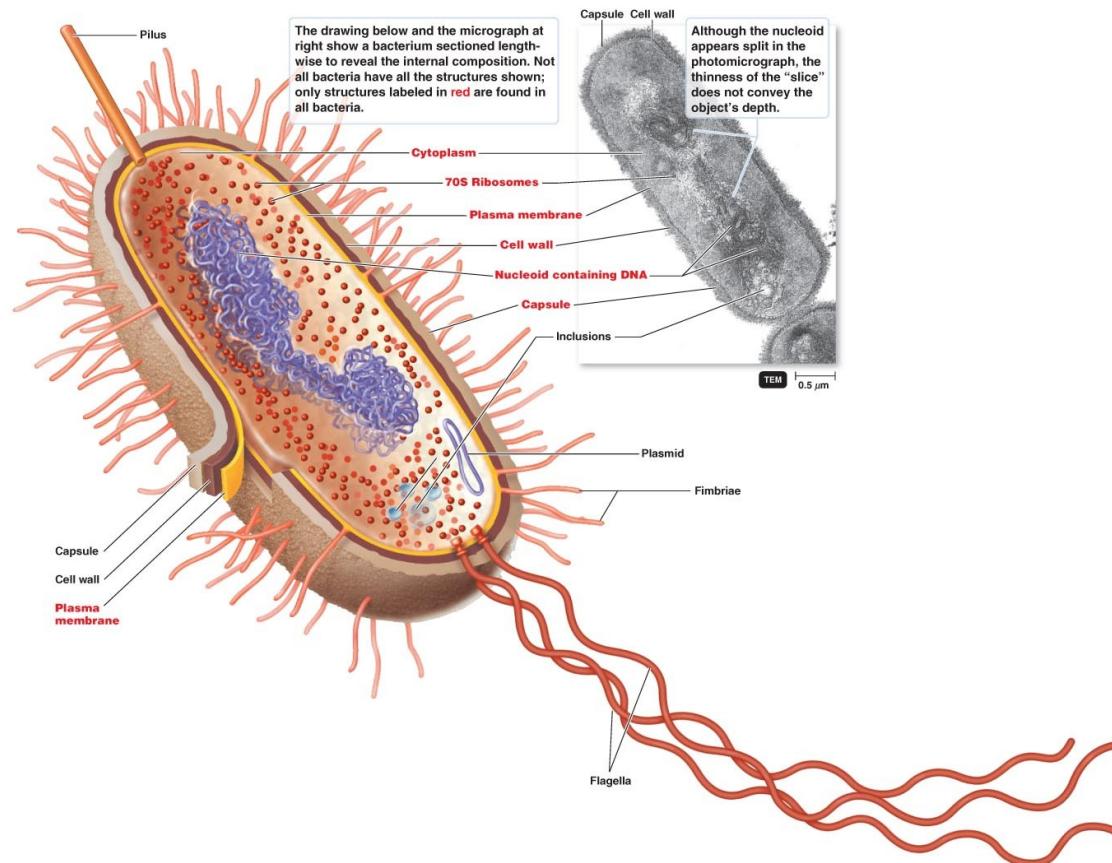
# **Check Your Understanding-2**

## **Check Your Understanding**

- ✓ How can you identify streptococci with a microscope?

4-2

# Figure 4.6 The Structure of a Prokaryotic Cell (1 of 2)



# **Structures External to the Cell Wall**

## **Learning Objectives**

4-3 Describe the structure and function of the glycocalyx.

4-4 Differentiate flagella, axial filaments, fimbriae, and pili.

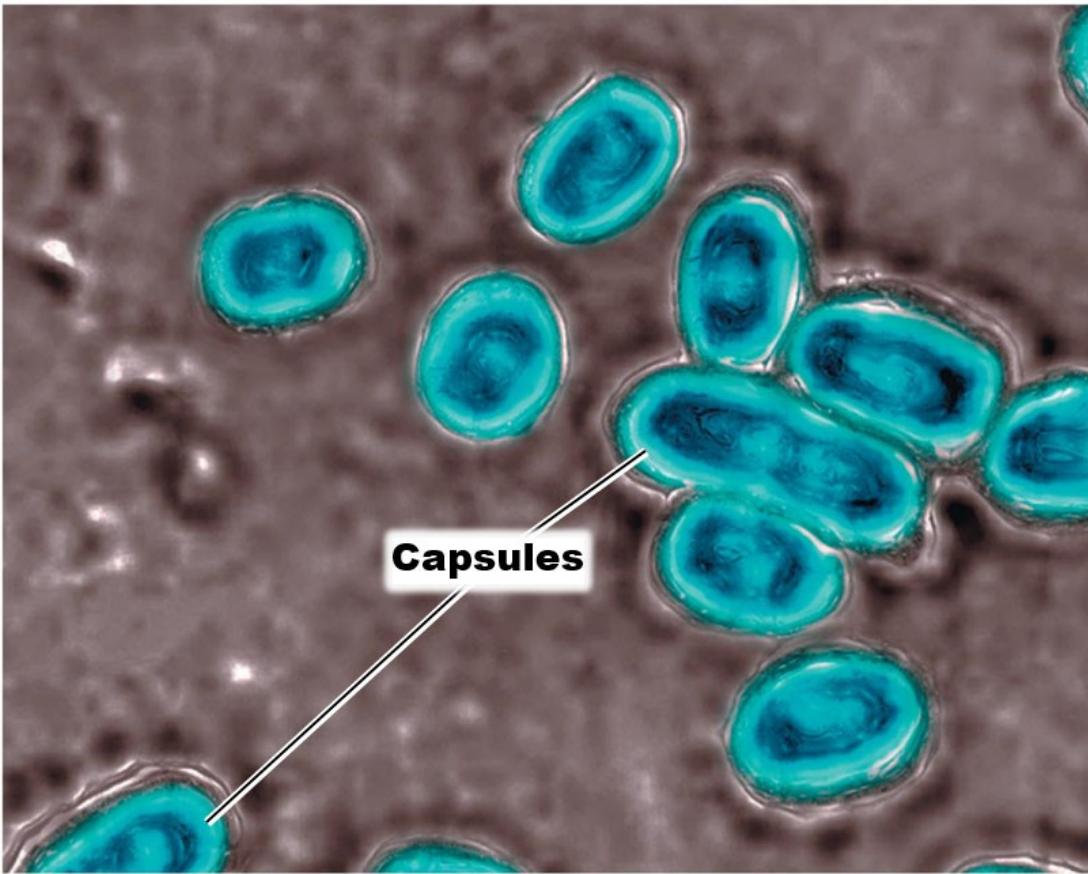
# Glycocalyx (1 of 2)

- External to the cell wall
- Viscous and gelatinous
- Made of polysaccharide and/or polypeptide
- Two types
  - **Capsule:** neatly organized and firmly attached
  - **Slime layer:** unorganized and loose

# Glycocalyx (2 of 2)

- Contribute to virulence
  - Capsules prevent phagocytosis
  - Extracellular polymeric substance helps form biofilms

# Figure 24.11 *Streptococcus Pneumoniae*, the Cause of Pneumococcal Pneumonia



TEM  
1  $\mu\text{m}$

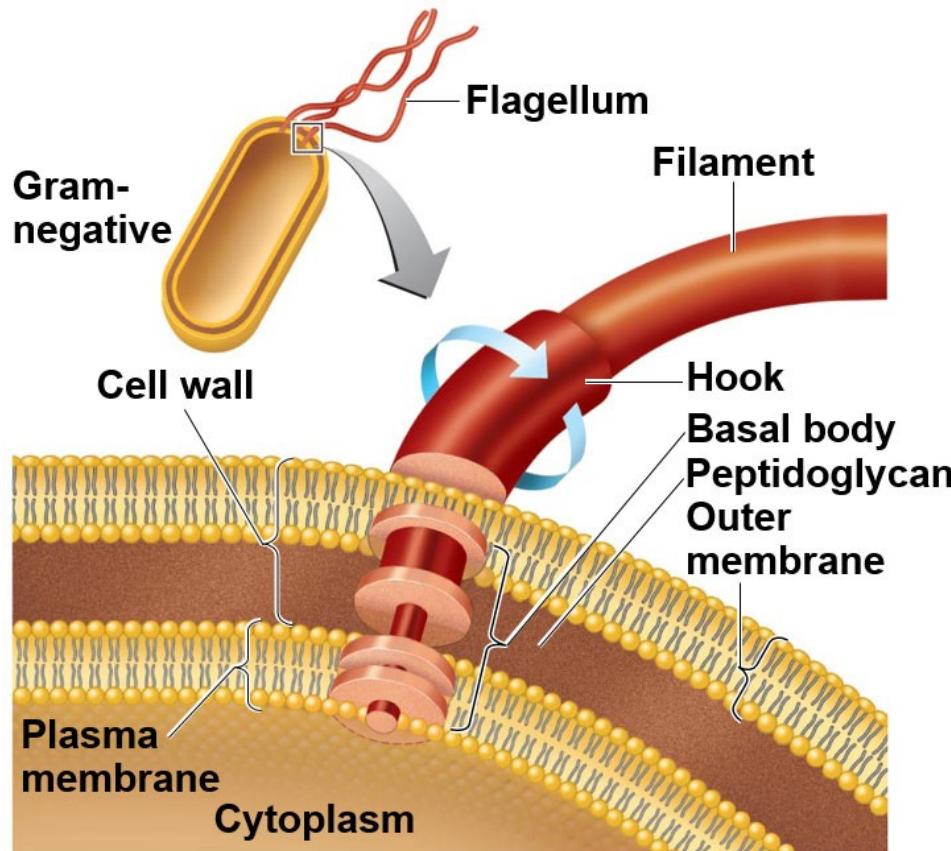
# Flagella (1 of 3)

- Filamentous appendages external of the cell
- Propel bacteria
- Made of protein flagellin

# Flagella (2 of 3)

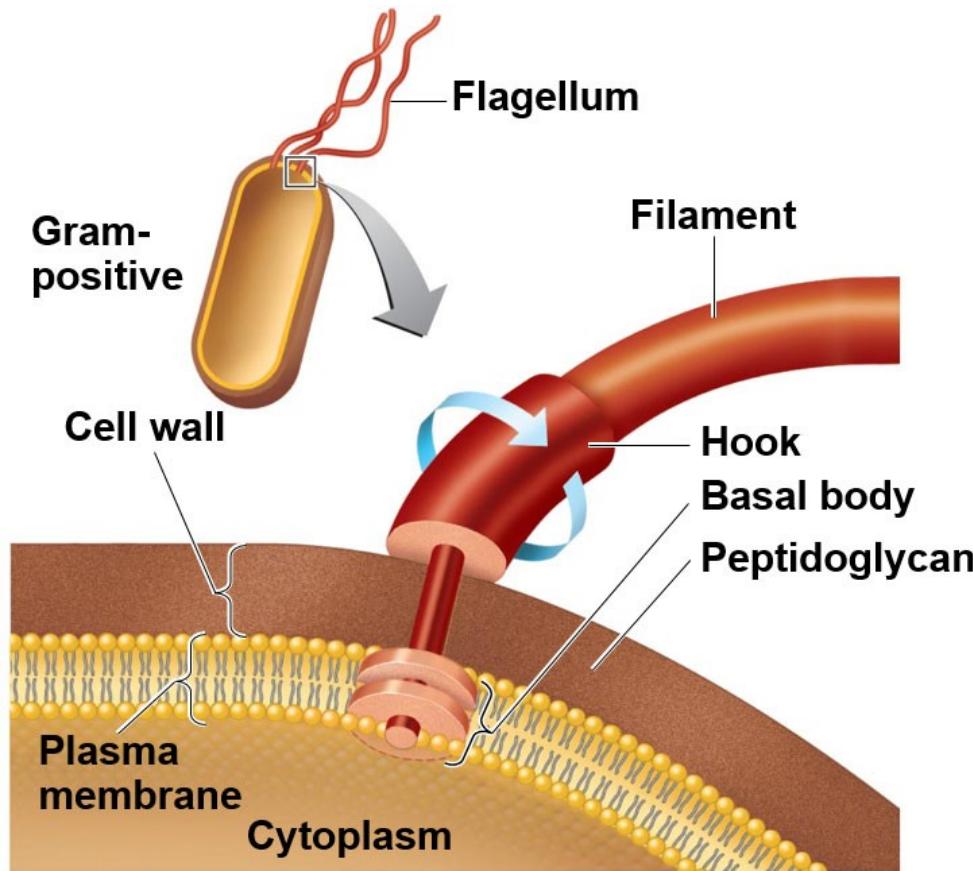
- Three parts:
  - Filament: outermost region
  - Hook: attaches to the filament
  - Basal body: consists of rod and pairs of rings; anchors flagellum to the cell wall and membrane

# Figure 4.8a The Structure of a Prokaryotic Flagellum



(a) Parts and attachment of a flagellum of a gram-negative bacterium

# Figure 4.8b The Structure of a Prokaryotic Flagellum



**(b)** Parts and attachment of a flagellum of a gram-positive bacterium

# Flagella: Structure

PLAY

**Animation: Flagella:  
Structure**

# Figure 4.7 Arrangements of Bacterial Flagella



SEM 1.5  $\mu\text{m}$

**(a)** Peritrichous



SEM 0.8  $\mu\text{m}$

**(b)** Monotrichous and polar



SEM 1.5  $\mu\text{m}$

**(c)** Lophotrichous and polar



SEM 4  $\mu\text{m}$

**(d)** Amphitrichous and polar

# Flagella: Arrangement

PLAY

**Animation: Flagella:  
Arrangement**

# Flagella (3 of 3)

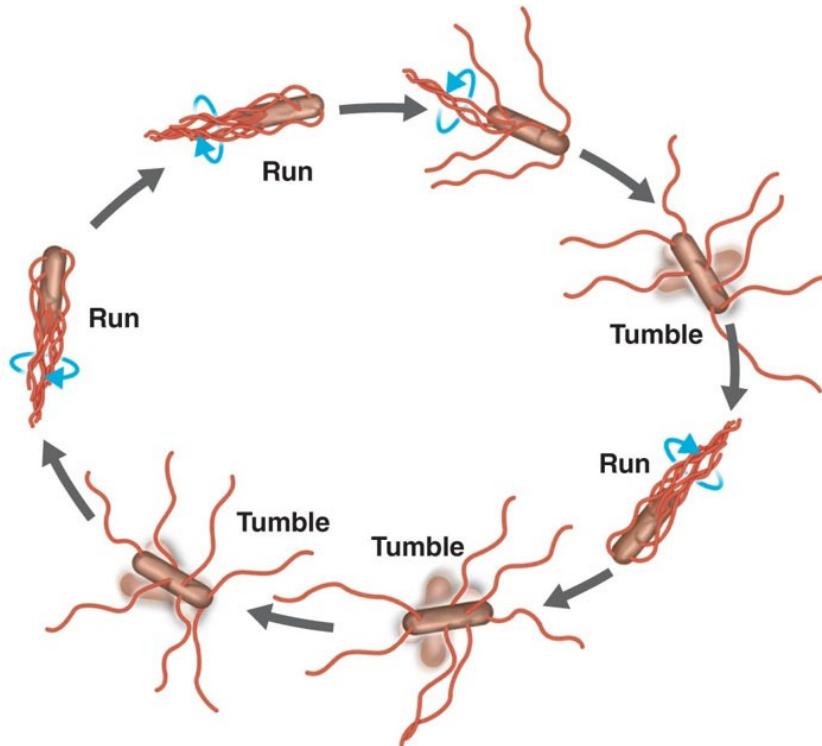
- Flagella allow bacteria to move toward or away from stimuli (**taxis**)
- Flagella rotate to "run" or "tumble"
- Flagella proteins are H antigens and distinguish among **serovars** (e.g., **Escherichia coli** O157:H7)

# Motility

PLAY

**Animation: Motility**

# Figure 4.9a Flagella and Bacterial Motility



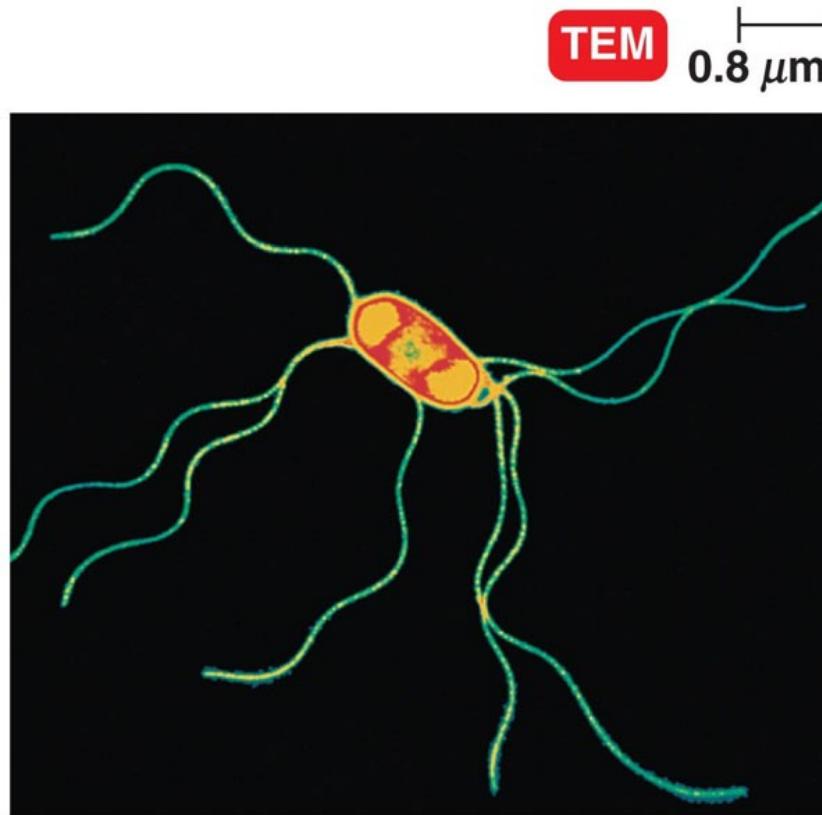
**(a)** A bacterium running and tumbling. Notice that the direction of flagellar rotation (blue arrows) determines which of these movements occurs. Gray arrows indicate direction of movement of the microbe.

# Flagella: Movement

PLAY

**Animation: Flagella:  
Movement**

# Figure 4.9b Flagella and Bacterial Motility

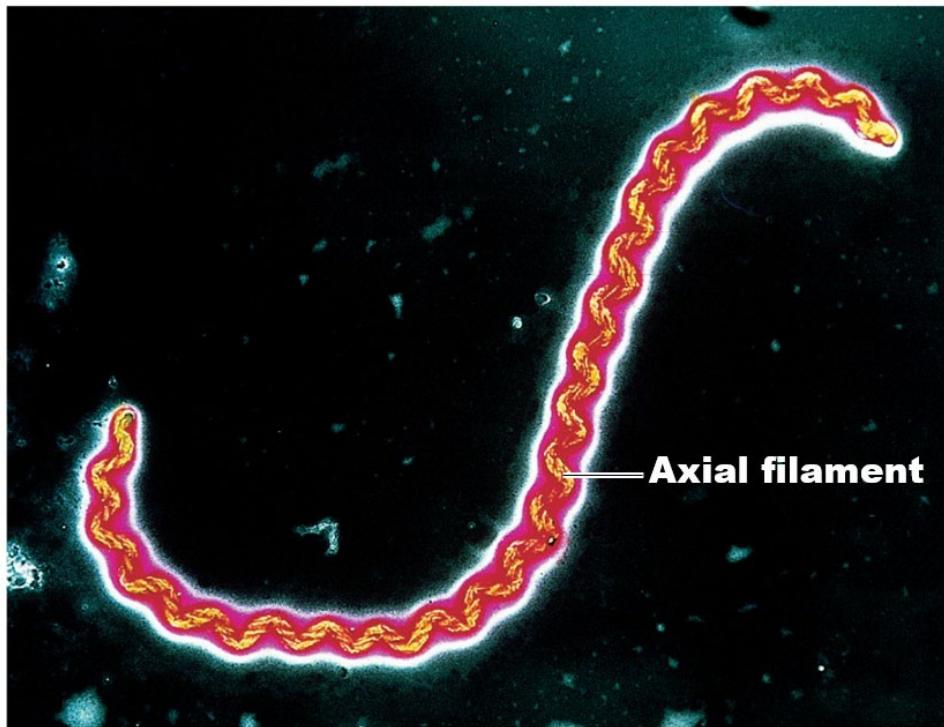


**(b)** A *Proteus* cell in the swarming stage may have more than 1000 peritrichous flagella.

# Axial Filaments

- Also called **endoflagella**
- Found in spirochetes
- Anchored at one end of a cell
- Rotation causes cell to move like a corkscrew

# Figure 4.10a Axial Filaments



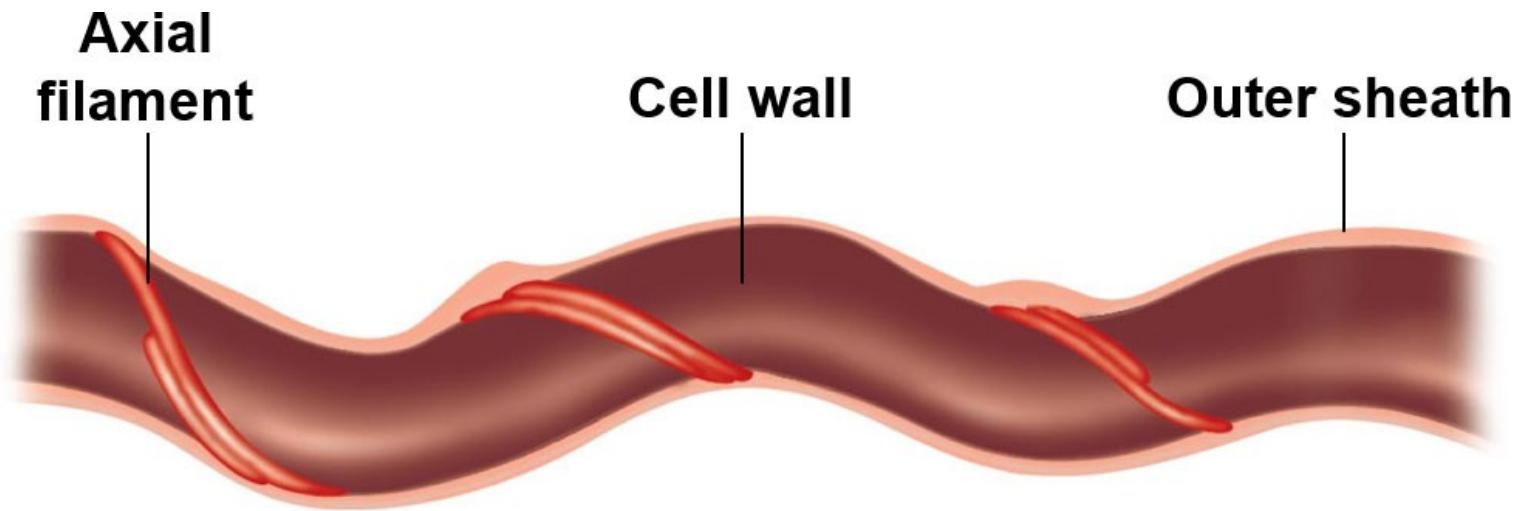
(a) A photomicrograph of the spirochete **Leptospira**, showing an axial filament

# Spirochetes

PLAY

**Animation: Spirochetes**

## Figure 4.10b Axial Filaments

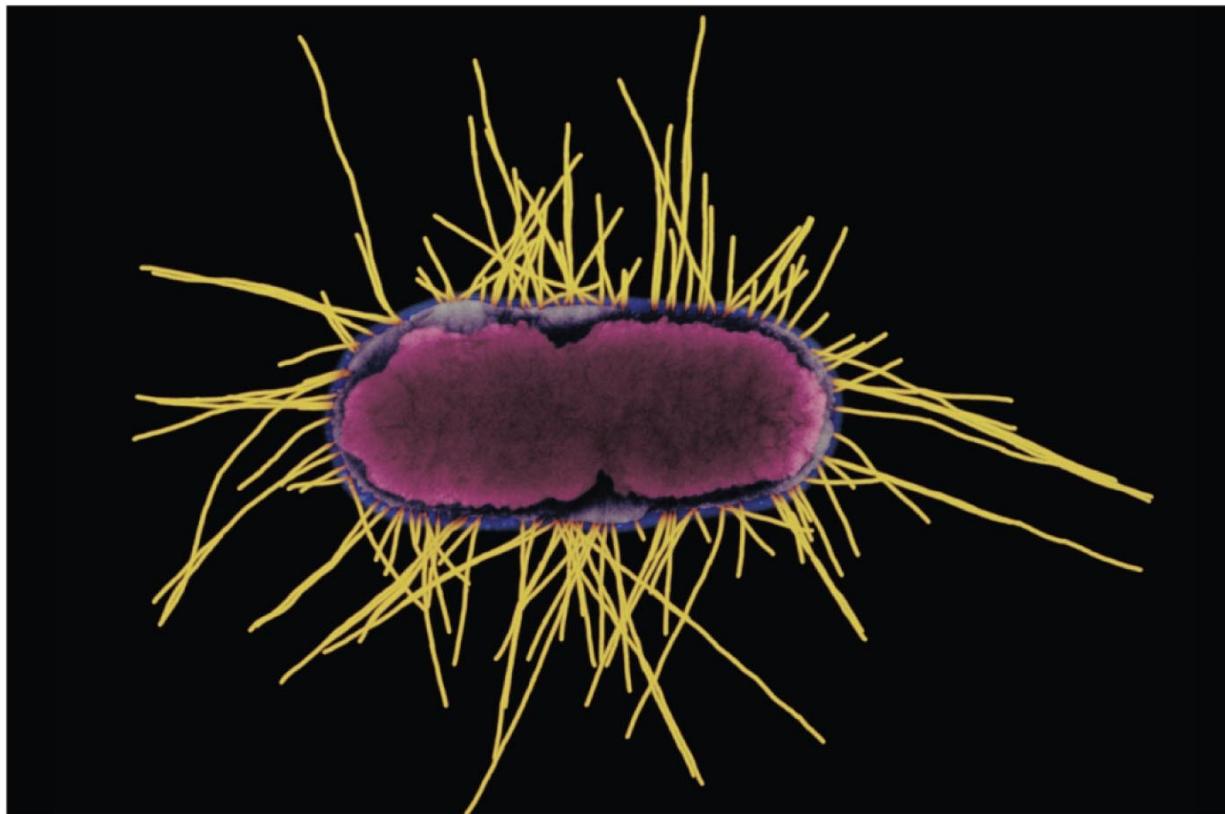


**(b)** A diagram of axial filaments wrapping around part of a spirochete

# Fimbriae and Pili (1 of 2)

- **Fimbriae**
  - Hairlike appendages that allow for attachment

# Figure 4.11 Fimbriae



TEM  
1  $\mu\text{m}$

# Fimbriae and Pili (2 of 2)

- **Pili**
  - Involved in motility (**gliding** and **twitching** motility)
  - **Conjugation pili** involved in DNA transfer from one cell to another

# **Check Your Understanding-3**

## **Check Your Understanding**

- ✓ Why are bacterial capsules medically important  
4-3
- ✓ How do bacteria move?  
4-4

# The Cell Wall (1 of 2)

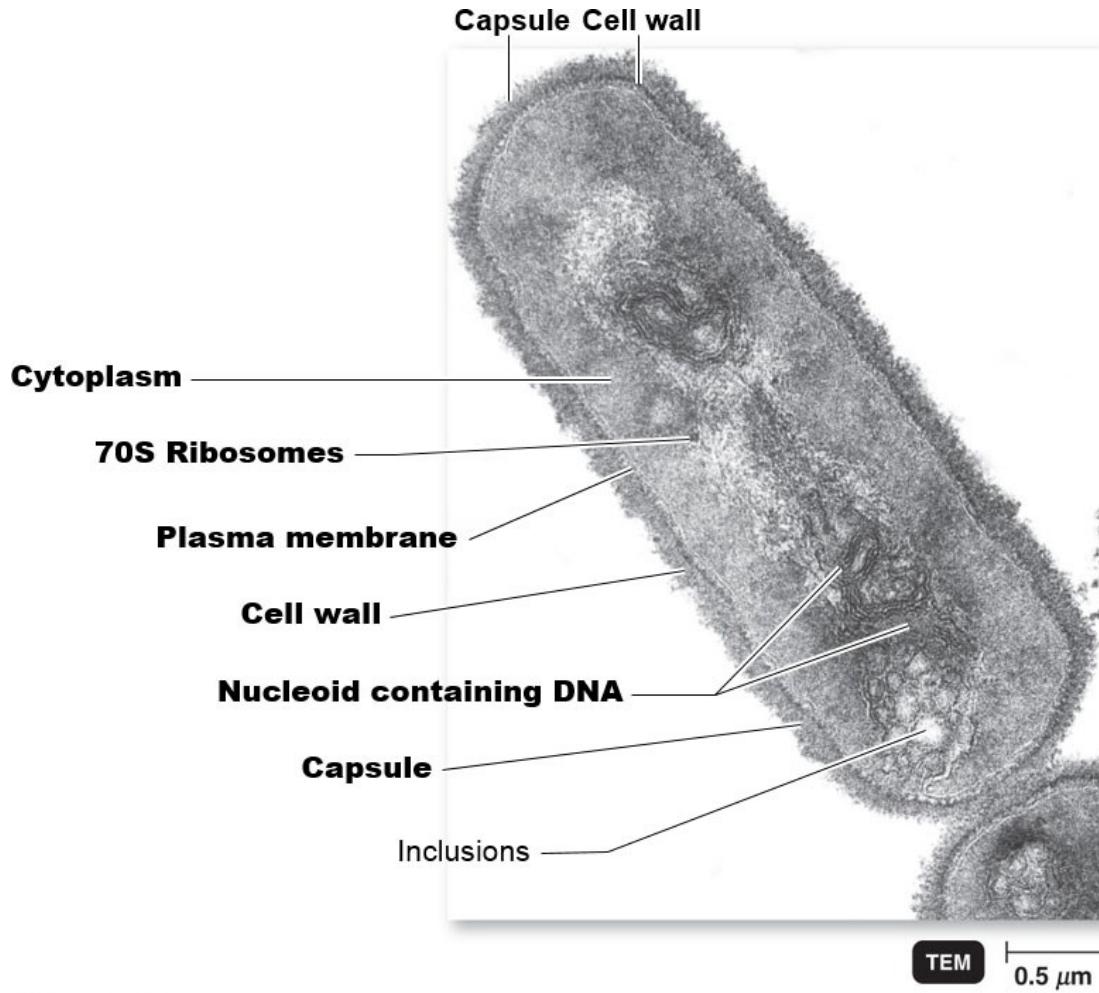
## Learning Objectives

- 4-5 Compare and contrast the cell walls of gram-positive bacteria, gram-negative bacteria, acid-fast bacteria, archaea, and mycoplasmas.
- 4-6 Compare and contrast archaea and mycoplasmas.
- 4-7 Differentiate **protoplast**, **spheroplast**, and *L form*.

# The Cell Wall (2 of 2)

- Prevents osmotic lysis and protects the cell membrane
- Made of **peptidoglycan** (in bacteria)
- Contributes to pathogenicity

# Figure 4.6 The Structure of a Prokaryotic Cell (2 of 2)

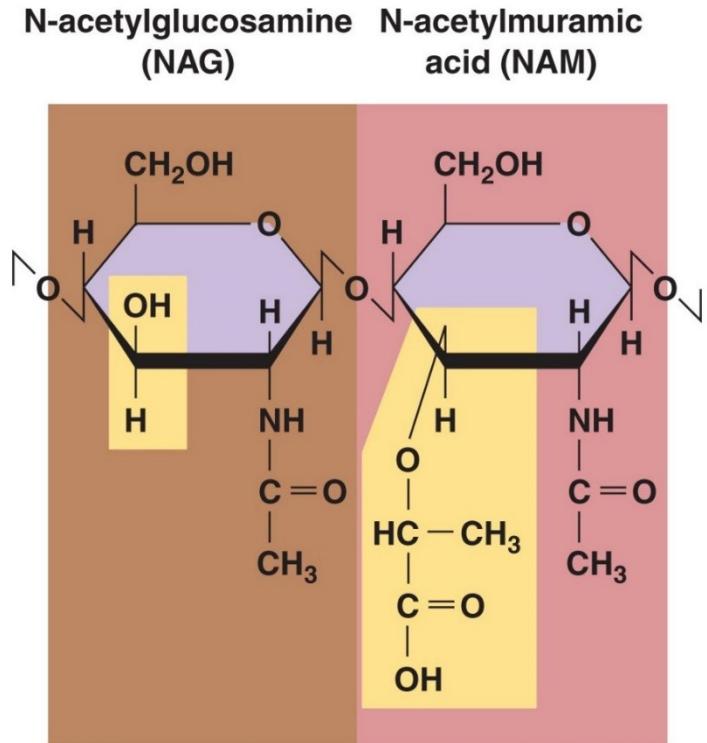


# Composition and Characteristics

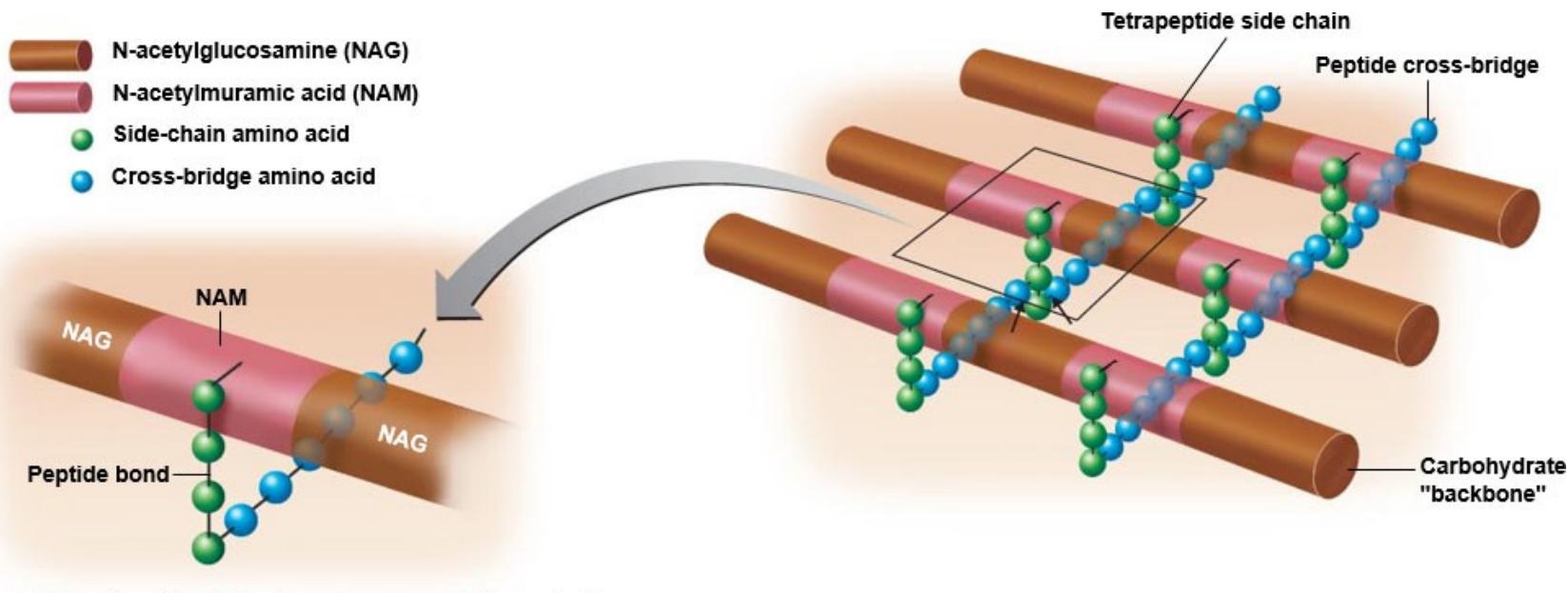
- Peptidoglycan
  - Polymer of a repeating disaccharide in rows:
    - N-acetylglucosamine (NAG)
    - N-acetylmuramic acid (NAM)
- Rows are linked by polypeptides

# Figure 4.12 N-acetylglucosamine (NAG) and N-acetylmuramic Acid (NAM)

N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) joined as in a peptidoglycan.



# Figure 4.13a Bacterial Cell Walls



# Gram-Positive Cell Walls (1 of 3)

- Thick peptidoglycan
- Teichoic acids

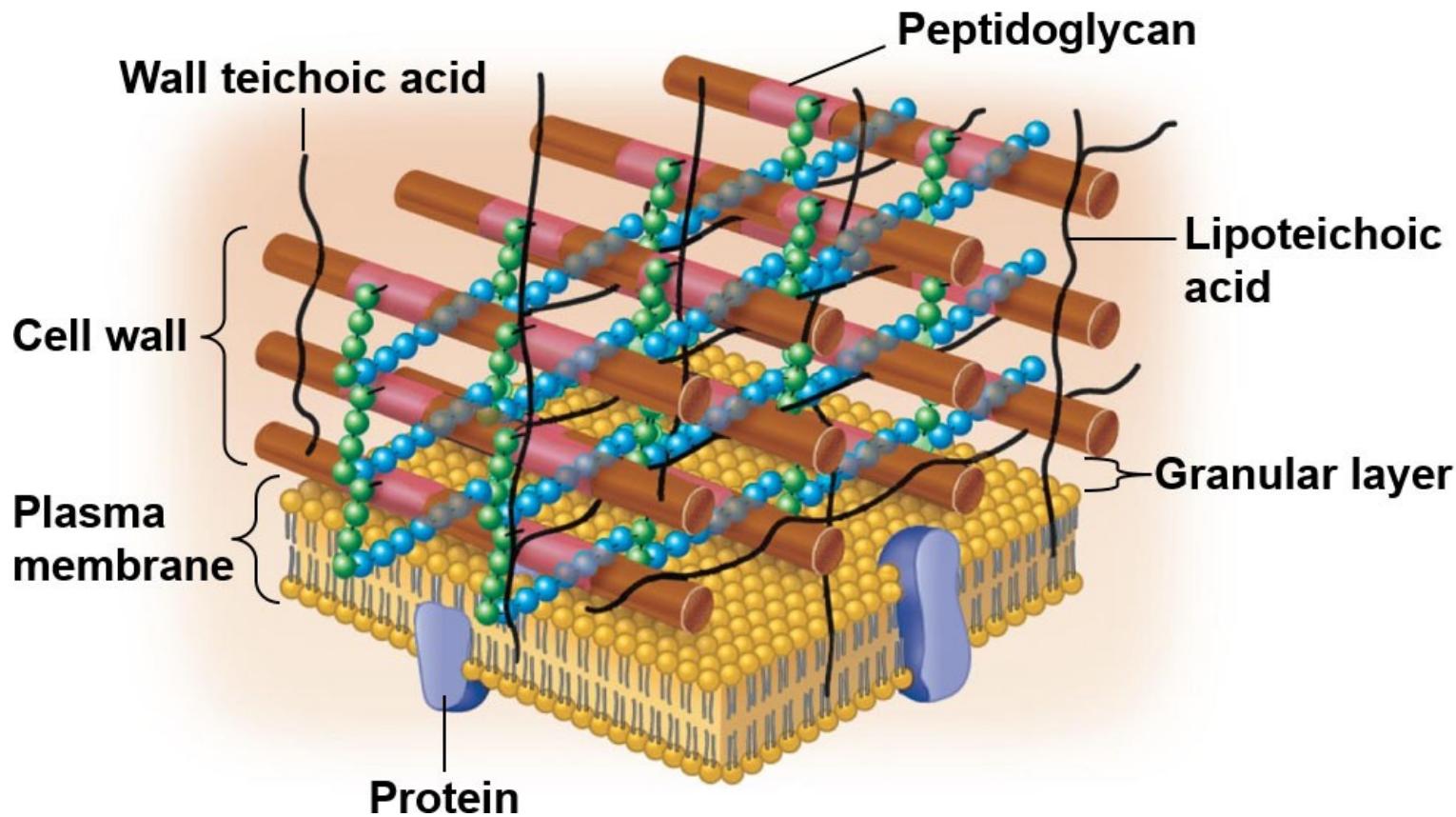
# Gram-Negative Cell Walls (1 of 4)

- Thin peptidoglycan
- Outer membrane
- Periplasmic space

# Gram-Positive Cell Walls (2 of 3)

- Teichoic acids
  - Lipoteichoic acid links cell wall to plasma membrane
  - Wall teichoic acid links the peptidoglycan
  - Carry a negative charge
  - Regulate movement of cations
- Polysaccharides and teichoic acids provide antigenic specificity

# Figure 4.13b Bacterial Cell Walls



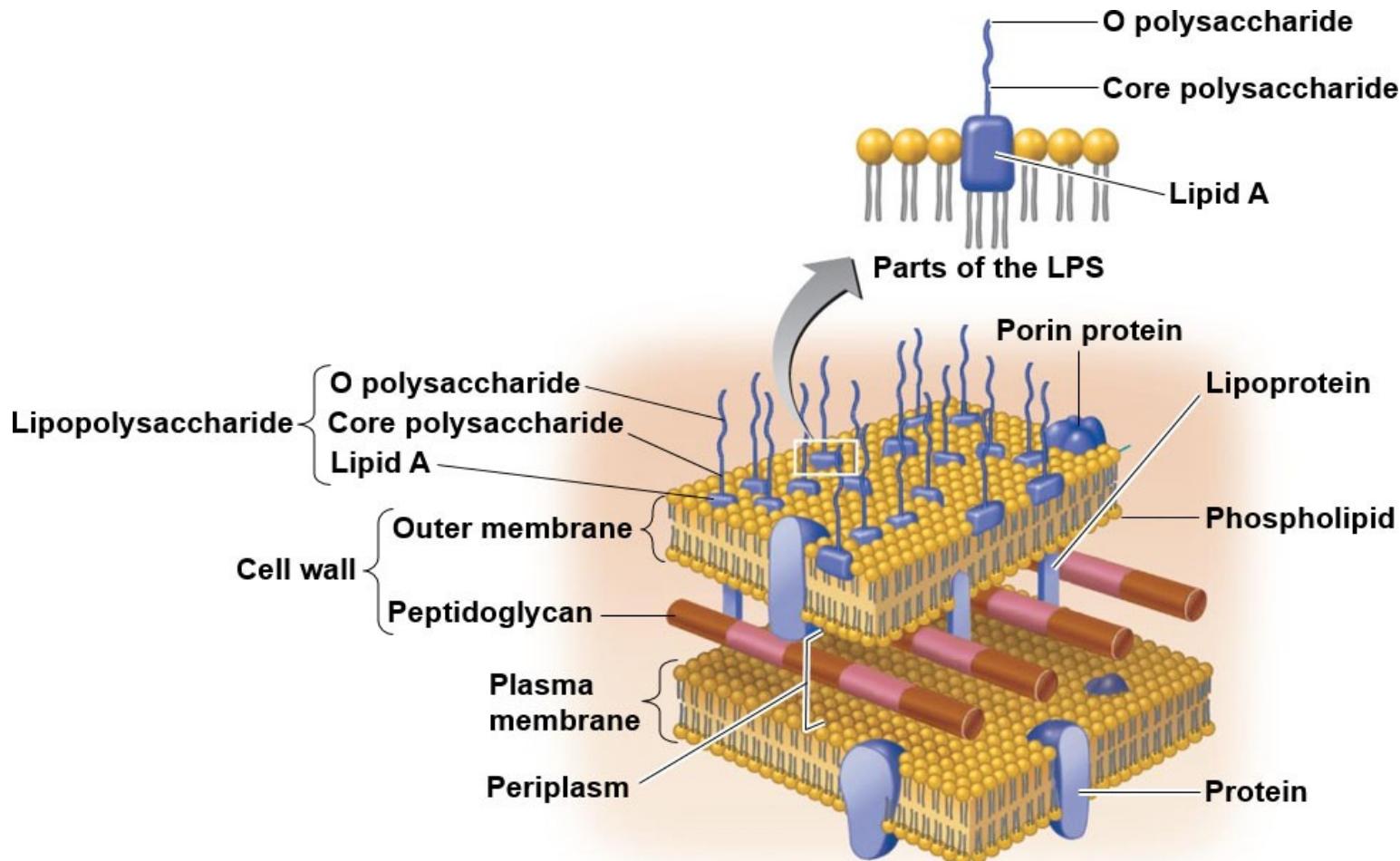
# Gram-Negative Cell Walls (2 of 4)

- Periplasm between the outer membrane and the plasma membrane contains peptidoglycan
- Outer membrane made of polysaccharides, lipoproteins, and phospholipids

# Gram-Negative Cell Walls (3 of 4)

- Protect from phagocytes, complement, and antibiotics
- Made of **lipopolysaccharide (LPS)**
  - **O polysaccharide** functions as antigen (e.g., **E.coli O157:H7**)
  - **Lipid A** is an endotoxin embedded in the top layer
- **Porins** (proteins) form channels through membrane

# Figure 4.13c Bacterial Cell Walls



# Cell Walls and the Gram Stain Mechanism

- Crystal violet-iodine crystals form inside cell
- Gram-positive
  - Alcohol dehydrates peptidoglycan
  - CV-I crystals do not leave
- Gram-negative
  - Alcohol dissolves outer membrane and leaves holes in peptidoglycan
  - CV-I washes out; cells are colorless
  - Safranin added to stain cells

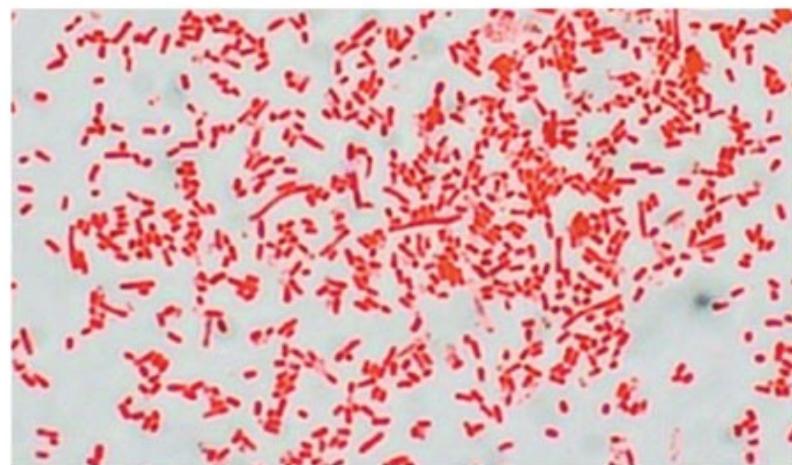
# Table 4.1 Some Comparative Characteristics of Gram-Positive and Gram-Negative Bacteria

Gram-Positive



LM  
12  $\mu\text{m}$

Gram-Negative



LM  
15  $\mu\text{m}$

# Gram-Positive Cell Walls (3 of 3)

- 2-rings in basal body of flagella
- Produce exotoxins
- High susceptibility to penicillin
- Disrupted by lysozyme

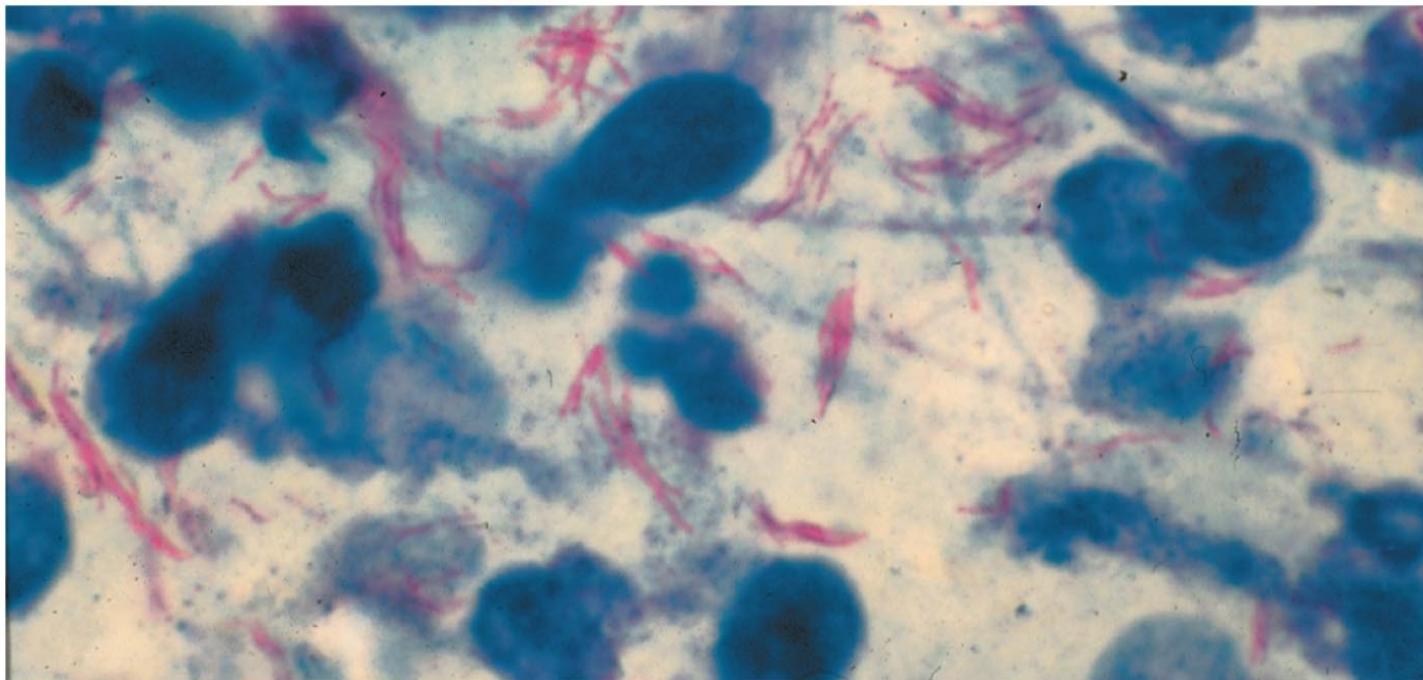
# Gram-Negative Cell Walls (4 of 4)

- 4-rings in basal body of flagella
- Produce endotoxins and exotoxins
- Low susceptibility to penicillin

# Atypical Cell Walls (1 of 2)

- Acid-fast cell walls
  - Like gram-positive cell walls
  - Waxy lipid (**mycolic acid**) bound to peptidoglycan
  - **Mycobacterium**
  - **Nocardia**
  - Stain with carbolfuchsin

# Figure 24.7 *Mycobacterium* Tuberculosis



LM  
2.5  $\mu\text{m}$

# Atypical Cell Walls (2 of 2)

- Mycoplasmas
  - Lack cell walls
  - Sterols in plasma membrane
- Archaea
  - Wall-less, or
  - Walls of pseudomurein (lack NAM and D-amino acids)

# Damage to the Cell Wall (1 of 2)

- Lysozyme hydrolyzes bonds in peptidoglycan
- Penicillin inhibits peptide bridges in peptidoglycan
- **Protoplast** is a wall-less gram-positive cell
- **Spheroplast** is a wall-less gram-negative cell
  - Protoplasts and spheroplasts are susceptible to osmotic lysis
- **L forms** are wall-less cells that swell into irregular shapes

# **Check Your Understanding-4**

## **Check Your Understanding**

✓ Why are drugs that target cell wall synthesis useful?

4-5

✓ Why are mycoplasmas resistant to antibiotics that interfere with cell wall synthesis?

4-6

✓ How do protoplasts differ from L forms?

4-7

# Structures Internal to the Cell Wall

## Learning Objectives

4-8 Describe the structure, chemistry, and functions of the prokaryotic plasma membrane.

4-9 Define **simple diffusion, facilitated diffusion, osmosis, active transport, and group translocation.**

4-10 Identify the functions of the nucleoid and ribosomes.

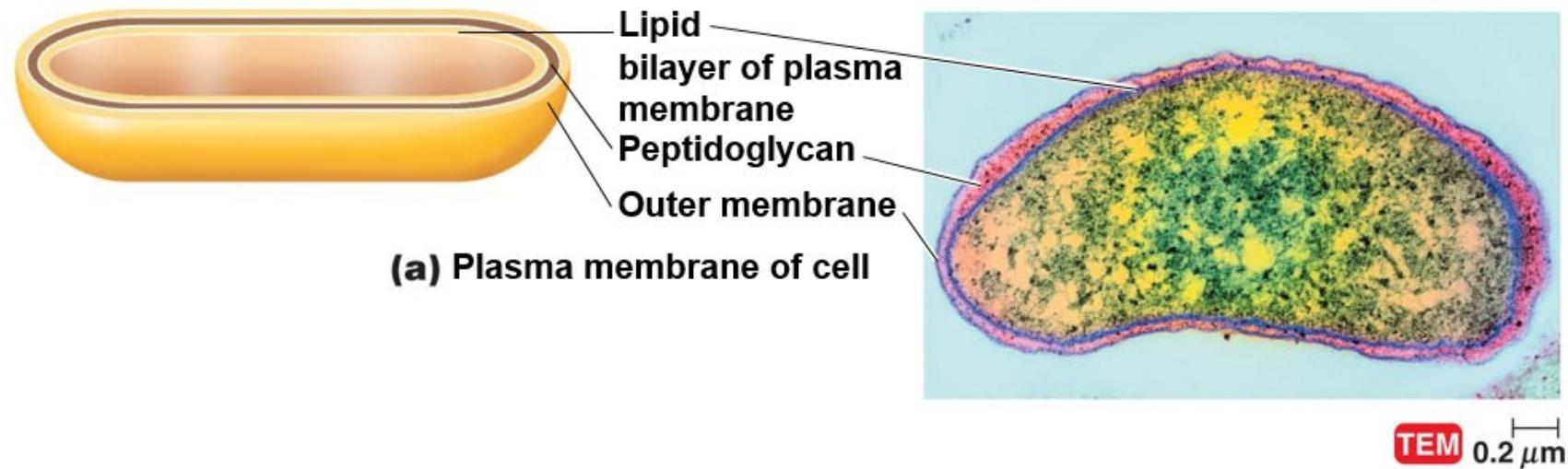
4-11 Identify the functions of four inclusions.

4-12 Describe the functions of endospores, sporulation, and endospore germination.

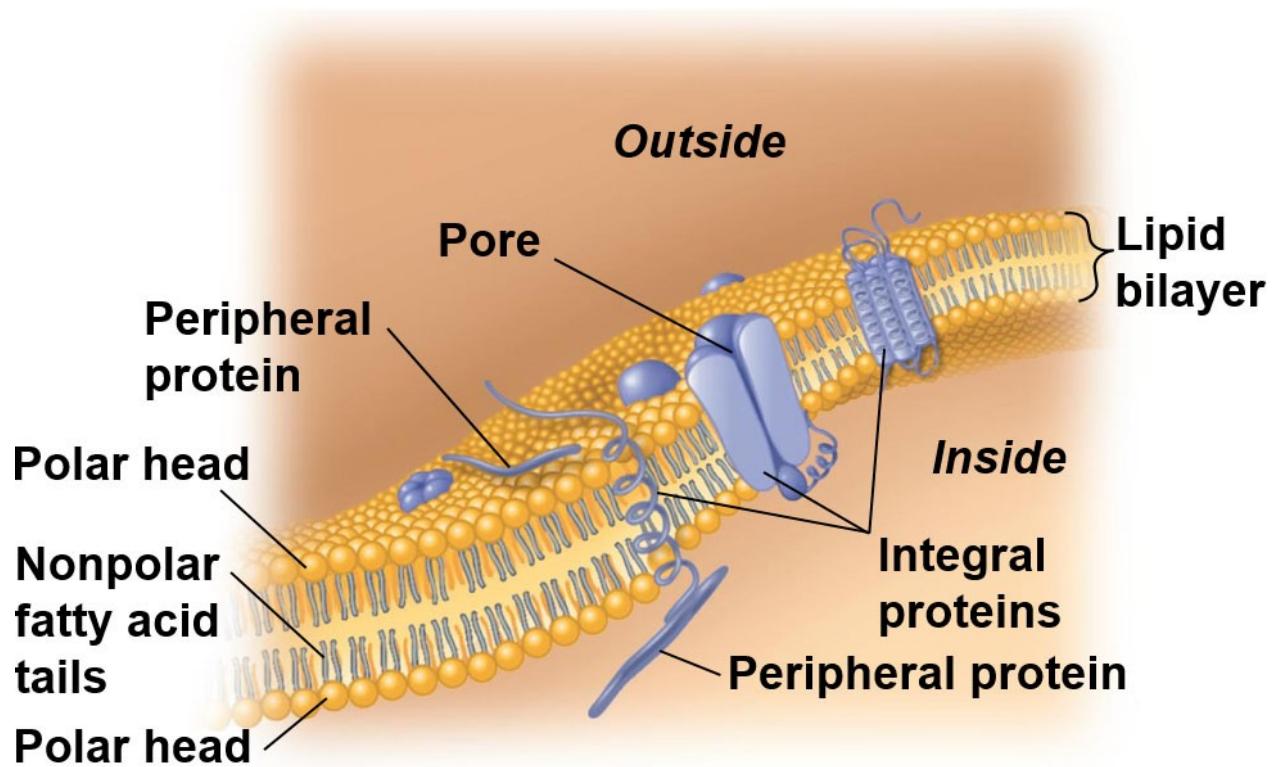
# The Plasma (Cytoplasmic) Membrane

- Phospholipid bilayer that encloses the cytoplasm
- Peripheral proteins on the membrane surface
- Integral and transmembrane proteins penetrate the membrane

# Figure 4.14a Plasma Membrane



# Figure 4.14b Plasma Membrane



(b) Lipid bilayer of plasma membrane

# Membrane Structure

PLAY

**Animation: Membrane  
Structure**

# Structure

- **Fluid mosaic model**
  - Membrane is as viscous as olive oil
  - Proteins move freely for various functions
  - Phospholipids rotate and move laterally
  - Self-sealing

# Functions (1 of 2)

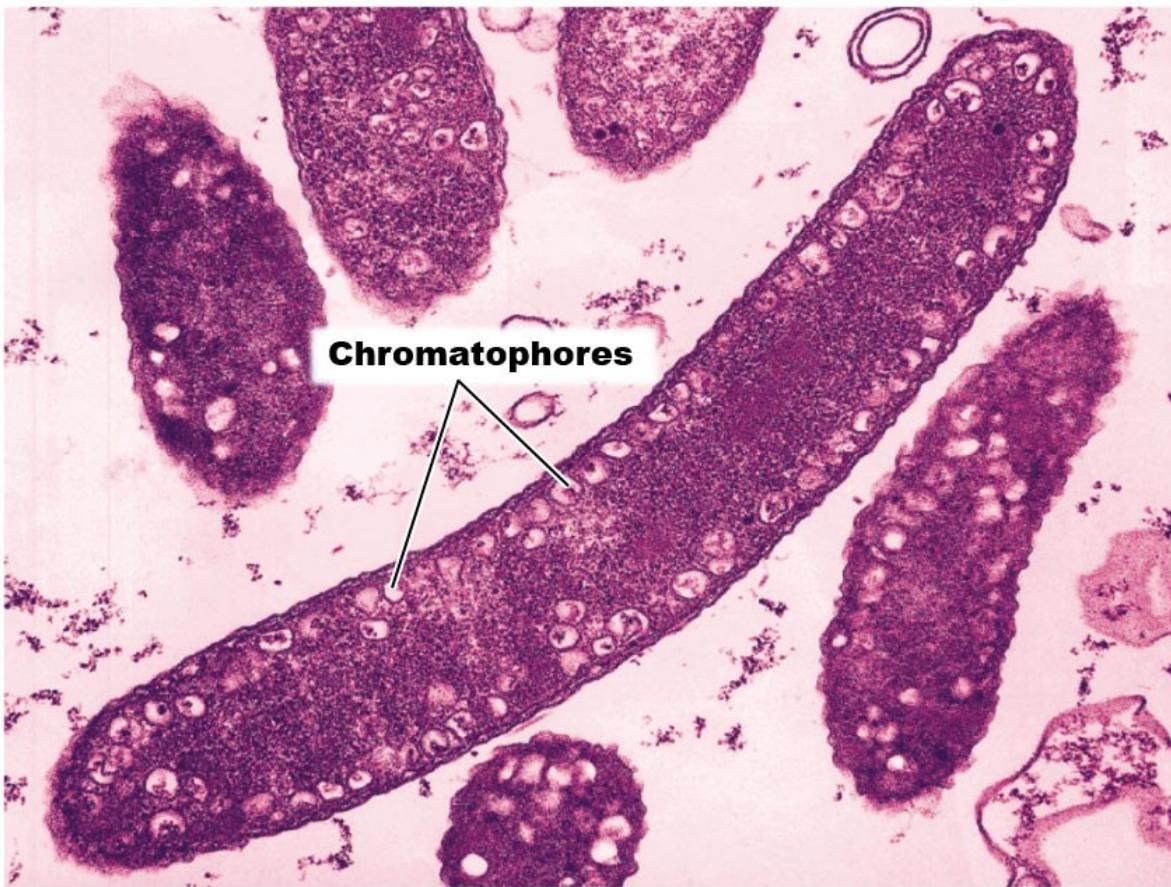
- The plasma membrane's **selective permeability** allows the passage of some molecules, but not others
- Contain enzymes for ATP production
- Some membranes have photosynthetic pigments on foldings called **chromatophores**

# Membrane Permeability

PLAY

**Animation: Membrane  
Permeability**

# Figure 4.15 Chromatophores



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# Functions (2 of 2)

- Damage to the membrane by alcohols, quaternary ammonium (detergents), and polymyxin antibiotics causes leakage of cell contents

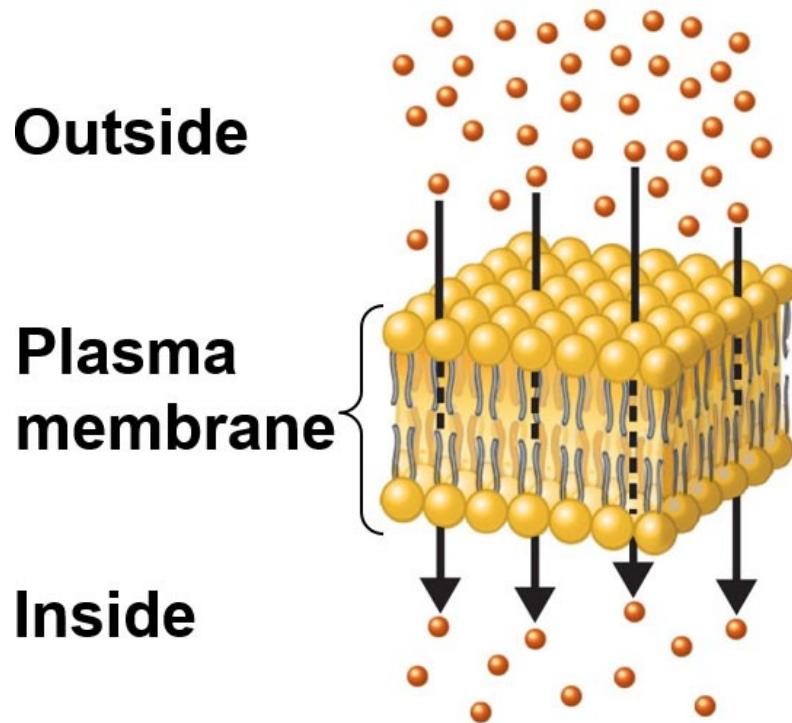
# The Movement of Materials Across Membranes

- Passive processes: substances move from high concentration to low concentration; no energy expended
- Active processes: substances move from low concentration to high concentration; energy expended

# Passive Processes (1 of 5)

- **Simple diffusion:** movement of a solute from an area of high concentration to an area of low concentration
- Continues until molecules reach equilibrium

# Figure 4.17a Passive Processes



**(a)** Simple diffusion through the lipid bilayer

# Passive Transport: Principles of Diffusion

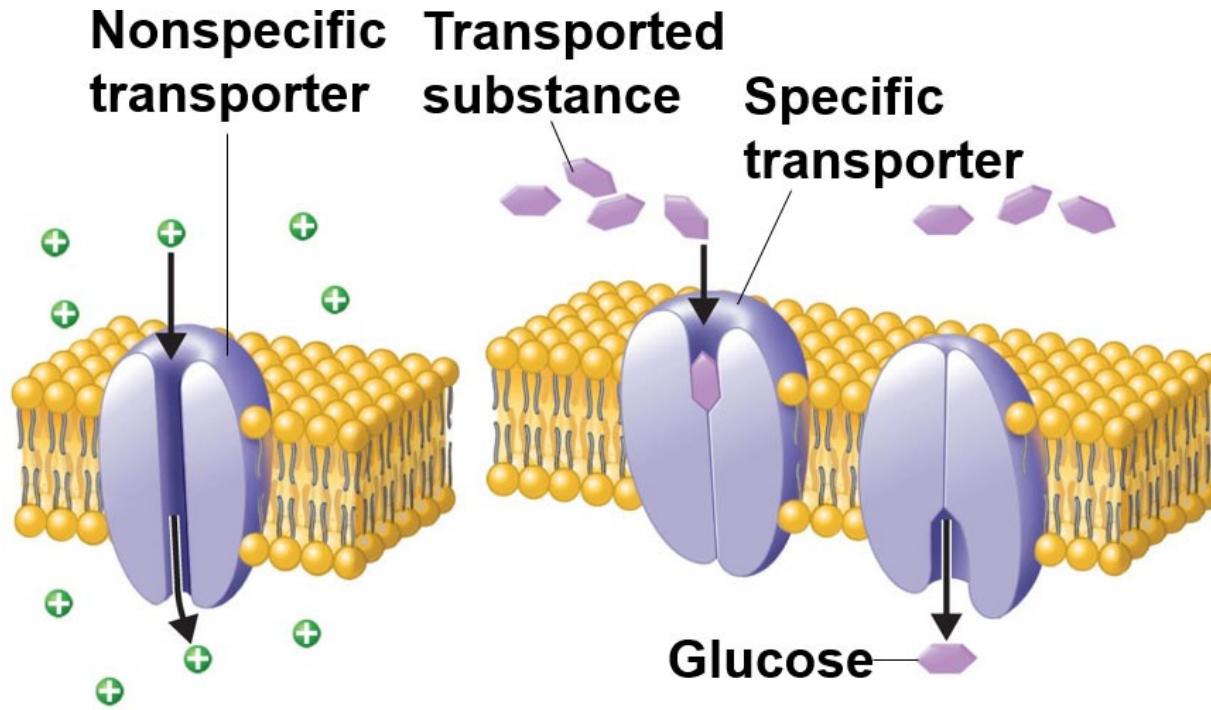
PLAY

**Animation: Passive Transport:  
Principles of Diffusion**

# Passive Processes (2 of 5)

- **Facilitated diffusion:** solute combines with a transporter protein in the membrane
- Transports ions and larger molecules across a membrane with the concentration gradient

# Figure 4.17b-c Passive Processes



**(b)** Facilitated diffusion through a nonspecific transporter

**(c)** Facilitated diffusion through a specific transporter

# Passive Transport: Special Types of Diffusion

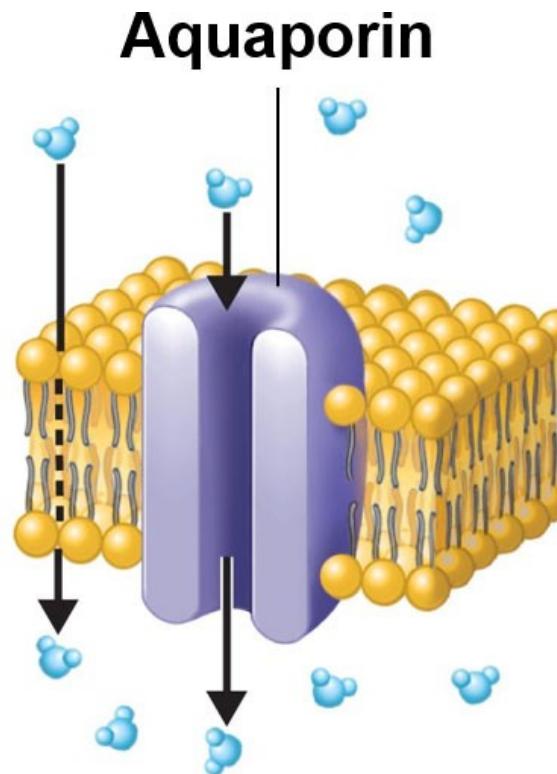
PLAY

**Animation: Passive Transport:  
Special Types of Diffusion**

# Passive Processes (3 of 5)

- **Osmosis:** the movement of water across a selectively permeable membrane from an area of high water to an area of lower water concentration
- Through lipid layer
- Aquaporins (water channels)

# Figure 4.17d Passive Processes

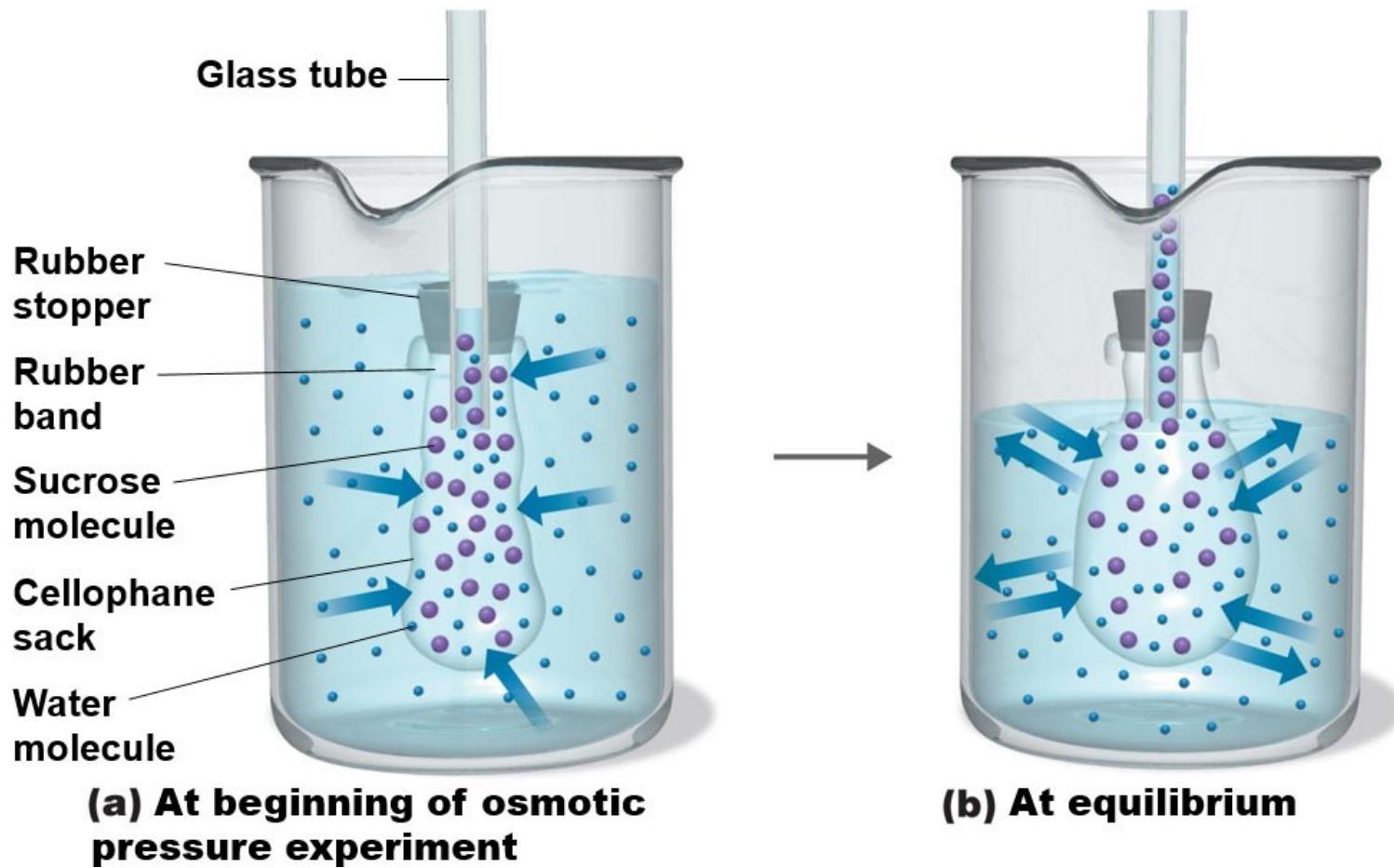


(d) Osmosis through the lipid bilayer (left) and an aquaporin (right)

# Passive Processes (4 of 5)

- **Osmotic pressure:** the pressure needed to stop the movement of water across the membrane

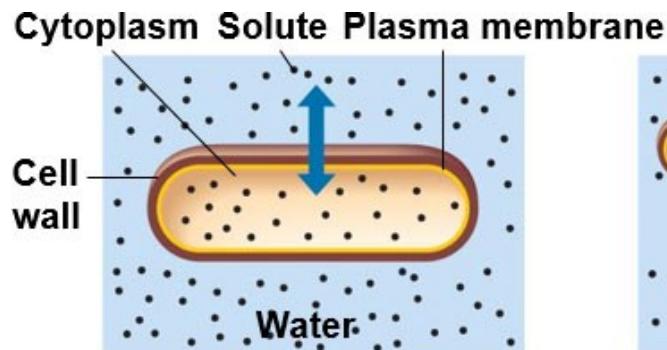
# Figure 4.18a-b The Principle of Osmosis



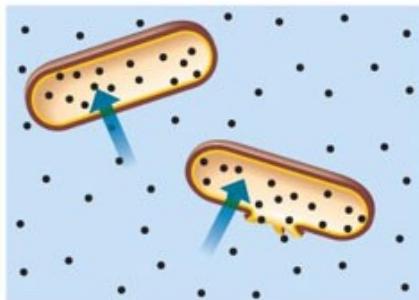
# Passive Processes (5 of 5)

- **Isotonic solution:** solute concentrations equal inside and outside of cell; water is at equilibrium
- **Hypotonic solution:** solute concentration is lower outside than inside the cell; water moves into cell
- **Hypertonic solution:** solute concentration is higher outside of cell than inside; water moves out of cell

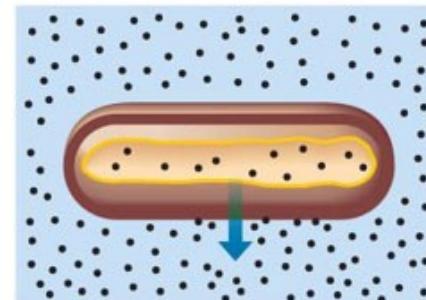
# Figure 4.18c-e The Principle of Osmosis



**(c) Isotonic solution.**  
No net movement of water occurs.



**(d) Hypotonic solution.**  
Water moves into the cell. If the cell wall is strong, it contains the swelling. If the cell wall is weak or damaged, the cell bursts (osmotic lysis).



**(e) Hypertonic solution.**  
Water moves out of the cell, causing its cytoplasm to shrink (plasmolysis).

# Active Processes

- **Active transport:** requires a transporter protein and ATP; goes against gradient
- **Group translocation:** requires a transporter protein and phosphoenolpyruvic acid (PEP); substance is altered as it crosses the membrane

# Active Transport: Overview

PLAY

**Animation: Active Transport:  
Overview**

# Active Transport: Types

PLAY

**Animation: Active Transport:  
Types**

# **Check Your Understanding-5**

## **Check Your Understanding**

- ✓ Which agents can cause injury to the bacterial plasma membrane?

4-8

- ✓ How are simple diffusion and facilitated diffusion similar? How are they different?

4-9

# Cytoplasm

- The substance inside the plasma membrane
- Eighty percent water plus proteins, carbohydrates, lipids, and ions
- Cytoskeleton

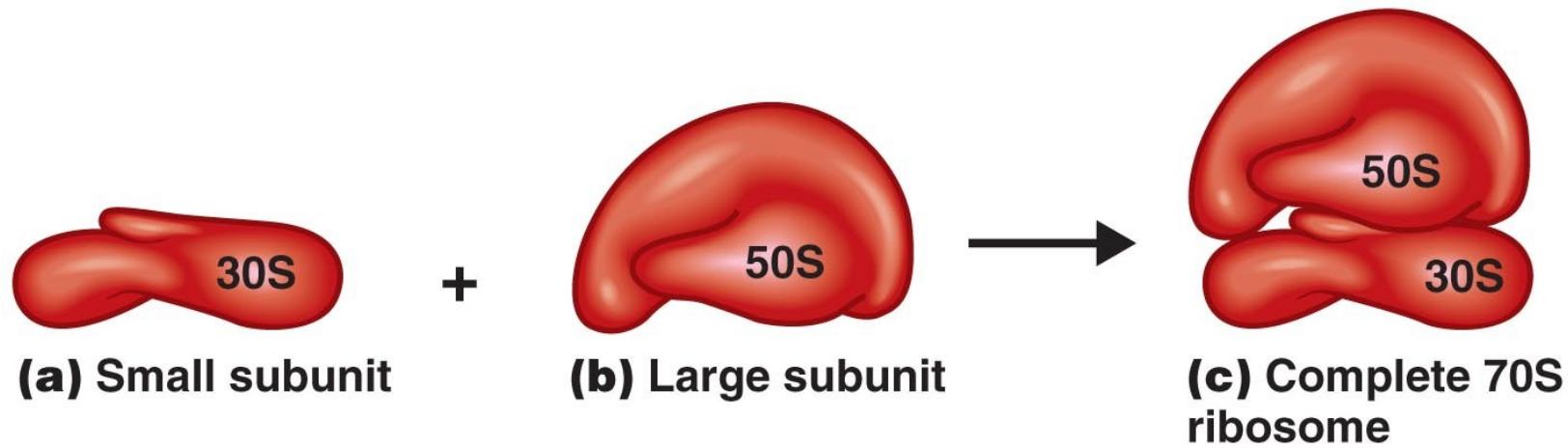
# The Nucleoid

- **Bacterial chromosome:** circular thread of DNA that contains the cell's genetic information
- **Plasmids:** extrachromosomal genetic elements; carry non-crucial genes (e.g., antibiotic resistance, production of toxins)

# Ribosomes

- Sites of protein synthesis
- Made of protein and ribosomal RNA
- 70S
  - 50S + 30S subunits

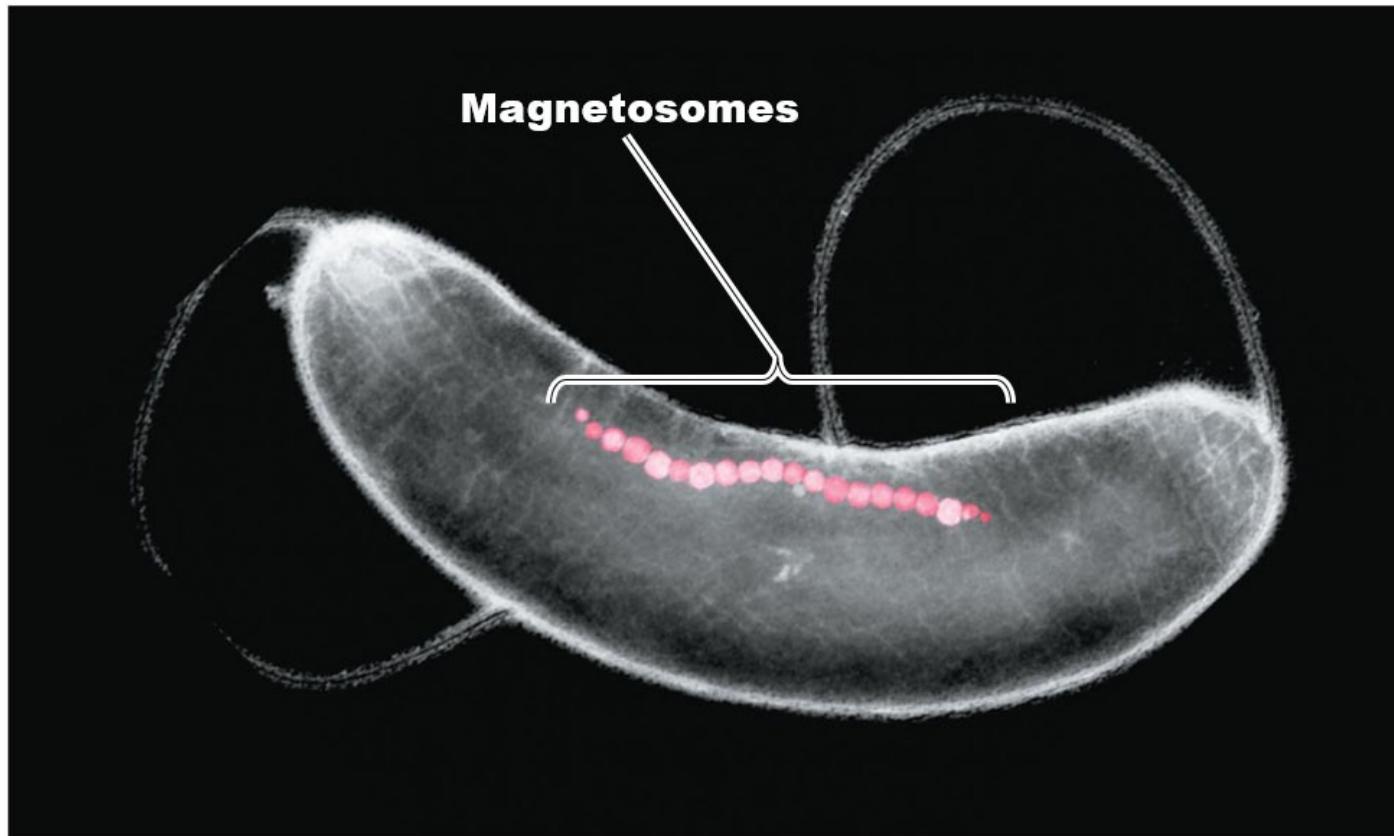
# Figure 4.19 The Prokaryotic Ribosome



# Inclusions

- **Metachromatic granules (volutin)**—phosphate reserves
- **Polysaccharide granules**—energy reserves
- **Lipid inclusions**—energy reserves
- **Sulfur granules**—energy reserves
- **Carboxysomes**—RuBisCO enzyme for CO<sub>2</sub> fixation during photosynthesis
- **Gas vacuoles**—protein-covered cylinders that maintain buoyancy
- **Magnetosomes**—iron oxide inclusions; destroy

# Figure 4.20 Magnetosomes



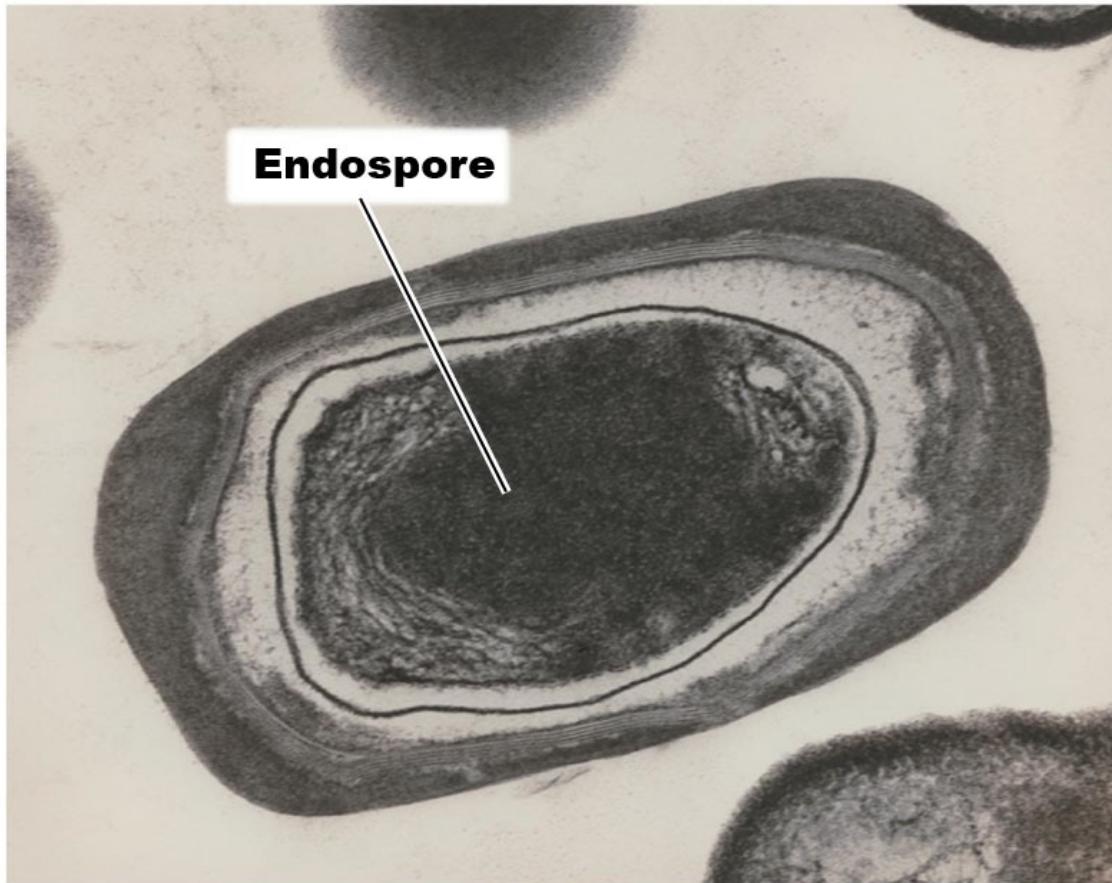
TEM

0.8  $\mu\text{m}$

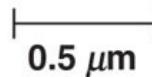
# Endospores

- Resting cells; produced when nutrients are depleted
- Resistant to desiccation, heat, chemicals, and radiation
- Produced by **Bacillus** and **Clostridium**
- **Sporulation:** endospore formation
- **Germination:** endospore returns to vegetative state

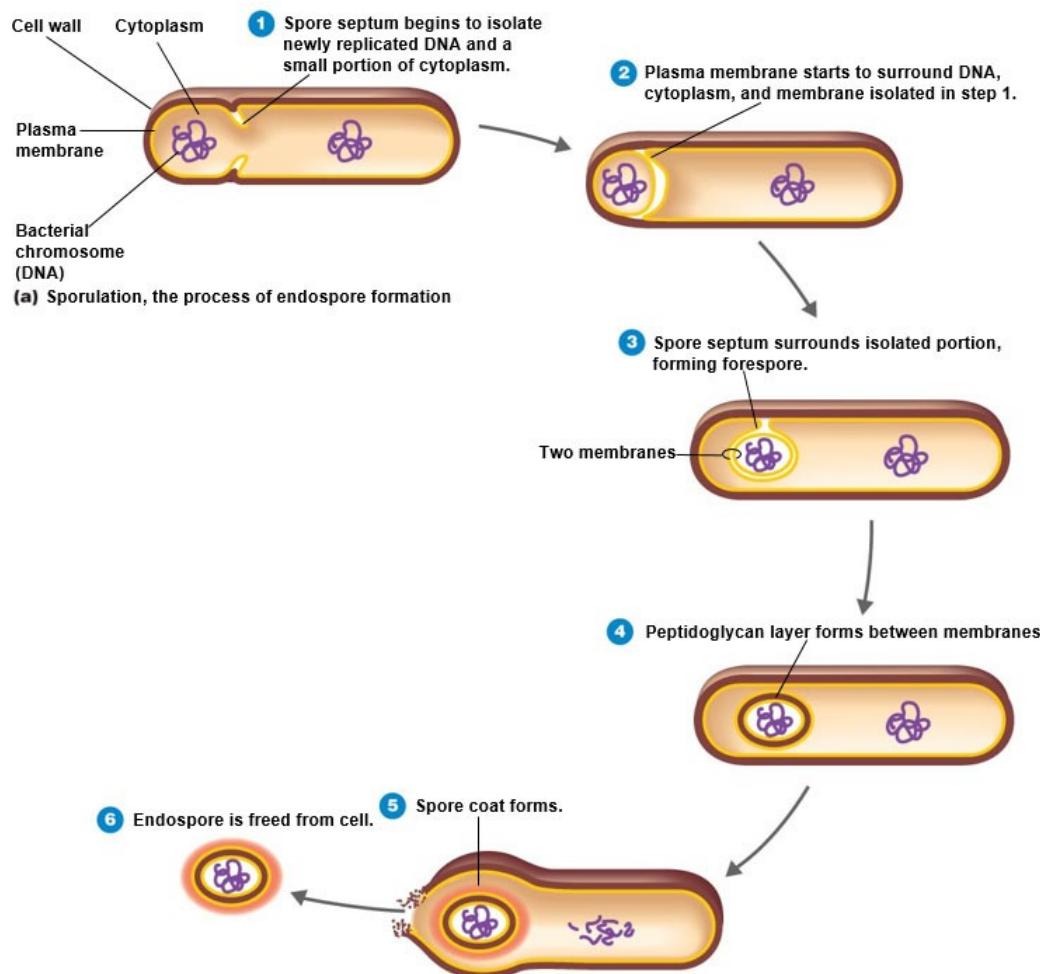
# Figure 4.21b Formation of Endospores by Sporulation



(b) An endospore of *Bacillus subtilis*

TEM  0.5  $\mu\text{m}$

# Figure 4.21a Formation of Endospores by Sporulation

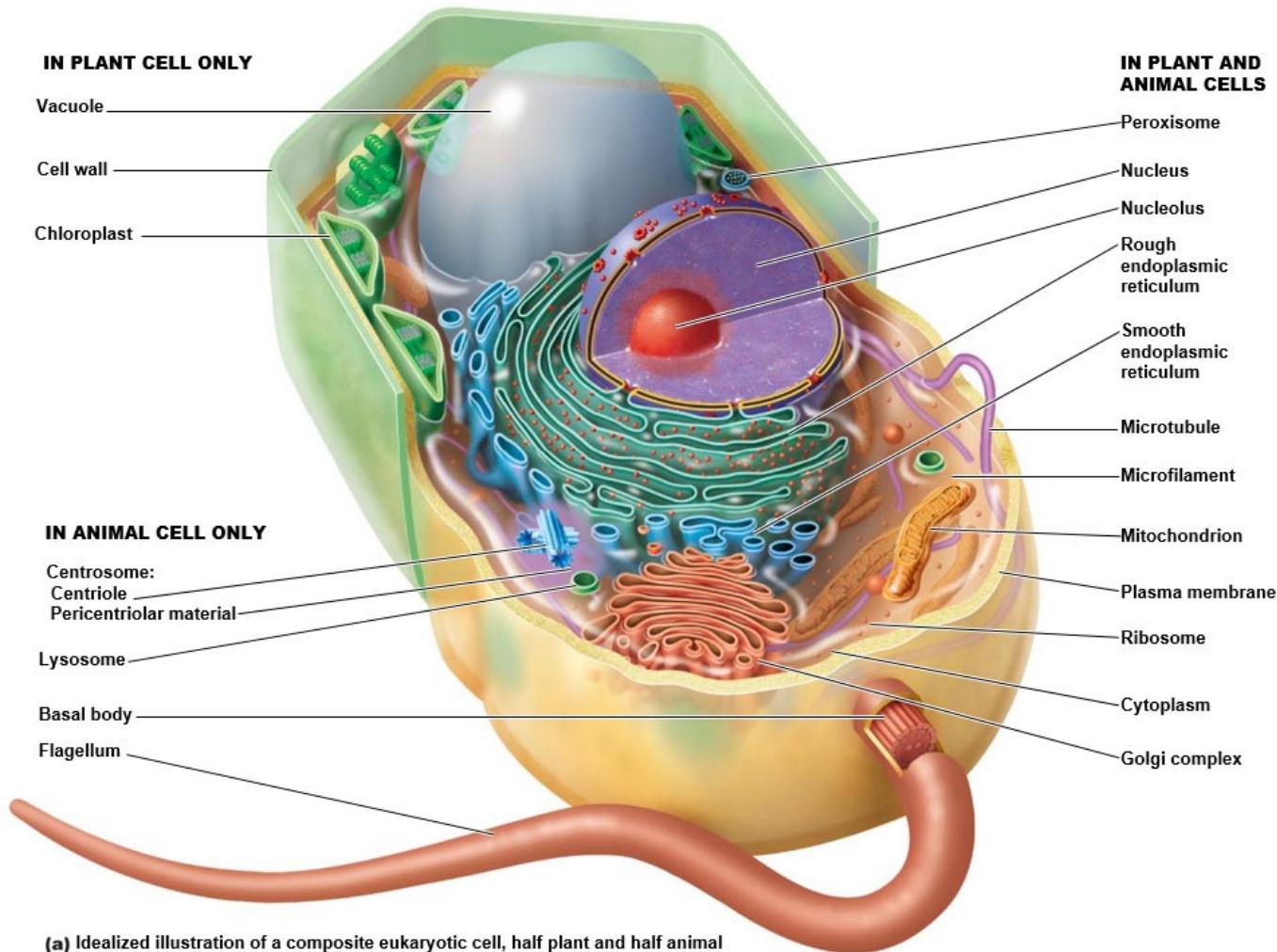


# **Check Your Understanding-6**

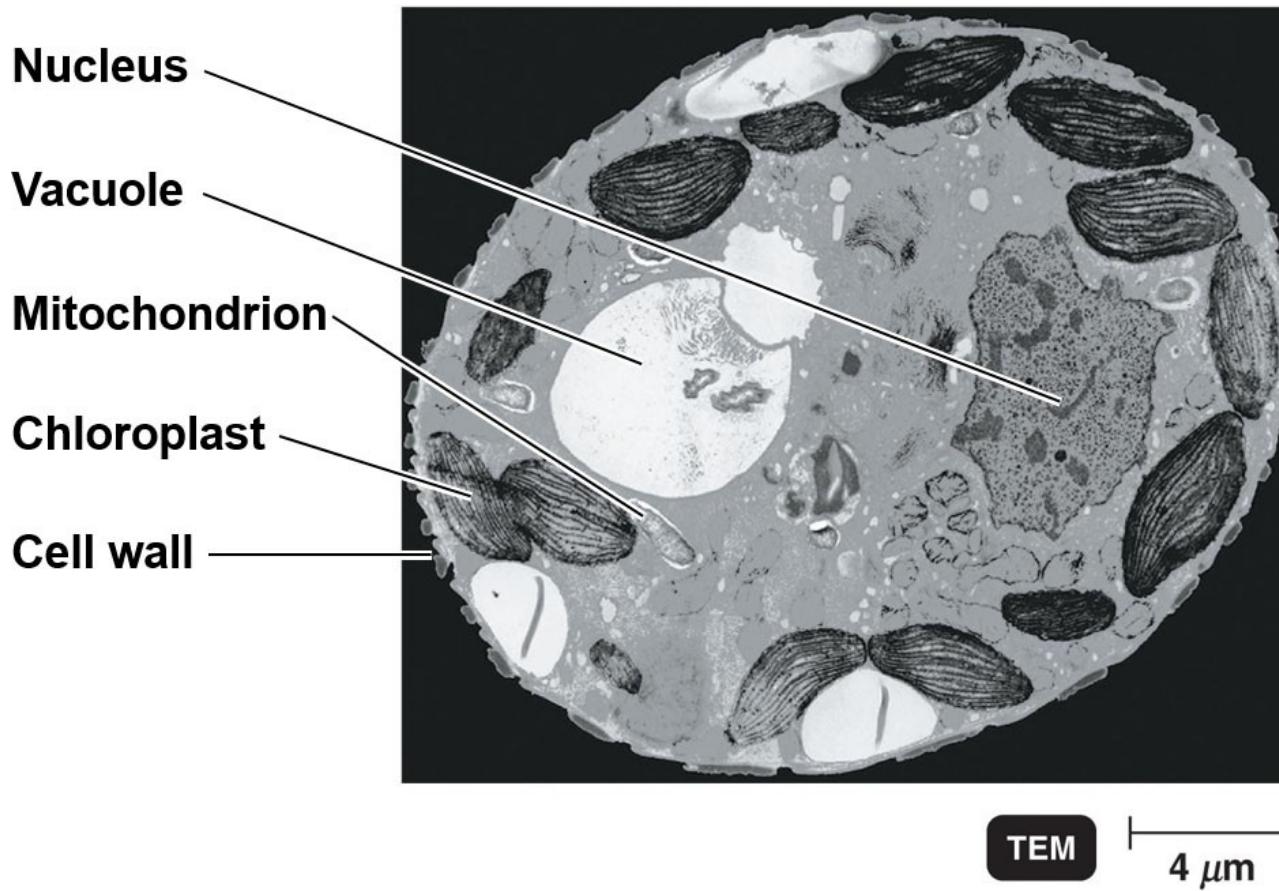
## **Check Your Understanding**

- ✓ Where is the DNA located in a prokaryotic cell  
4-10
- ✓ What is the general function of inclusions?  
4-11
- ✓ Under what conditions do endospores form?  
4-12

# Figure 4.22a Eukaryotic Cells Showing Typical Structures



# Figure 4.22b Eukaryotic Cells Showing Typical Structures



(b) Transmission electron micrograph of plant cell

# Flagella and Cilia (1 of 3)

## Learning Objective

4-13 Differentiate prokaryotic and eukaryotic flagella.

# Flagella and Cilia (2 of 3)

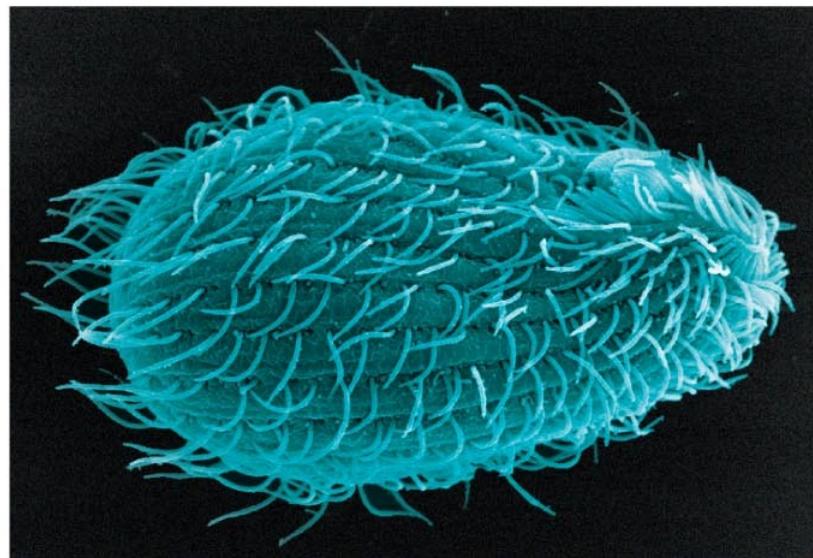
- Projections used for locomotion or moving substances along the cell surface
- **Flagella**—long projections; few in number
- **Cilia**—short projections; numerous

# Figure 4.23a-b Eukaryotic Flagella and Cilia



**(a)**

SEM  $5 \mu\text{m}$



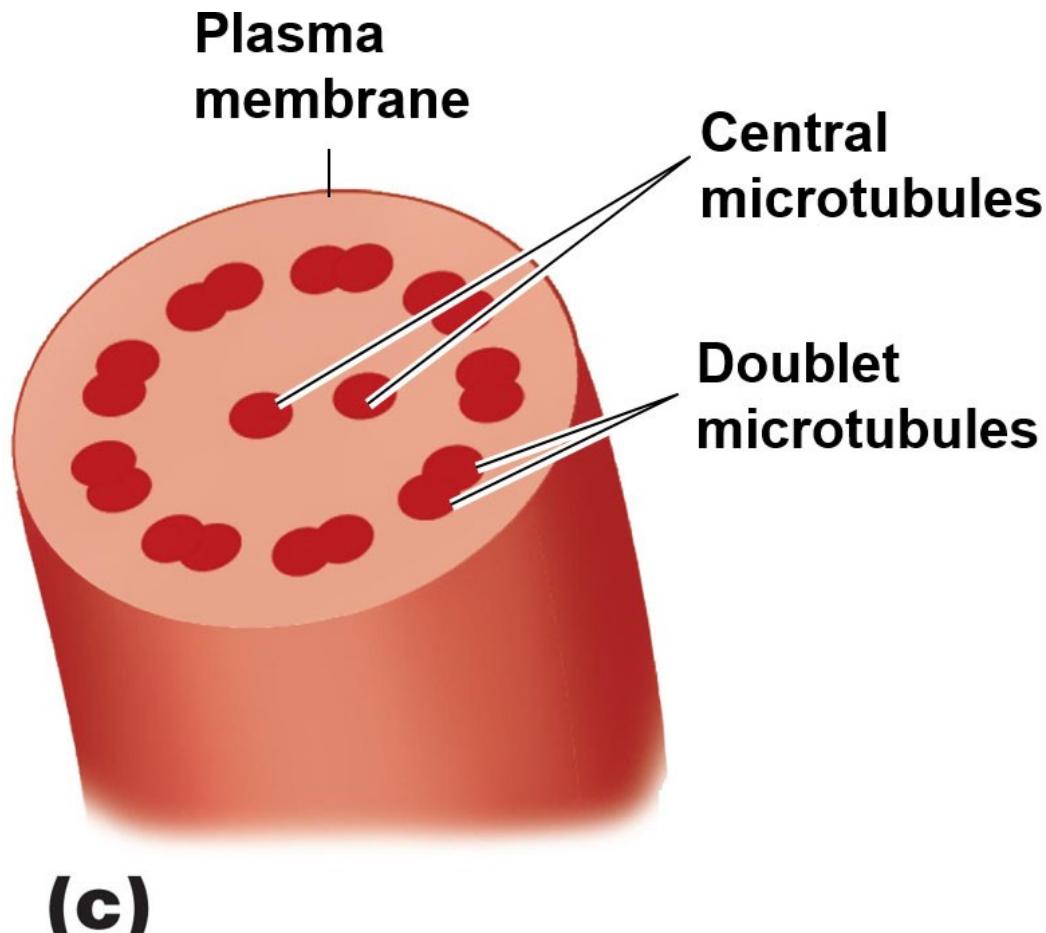
**(b)**

SEM  $10 \mu\text{m}$

# Flagella and Cilia (3 of 3)

- Both consist of **microtubules** made of the protein **tubulin**
- Microtubules are organized as nine pairs in a ring, plus two microtubules in the center (9 + 2 array)
- Allow flagella to move in a wavelike manner

# Figure 4.23c Eukaryotic Flagella and Cilia



# The Cell Wall and Glycocalyx (1 of 2)

## Learning Objective

4-14 Compare and contrast prokaryotic and eukaryotic cell walls and glycocalyxes.

# The Cell Wall and Glycocalyx (2 of 2)

- Cell wall
  - Found in plants, algae, and fungi
  - Made of carbohydrates (cellulose—plants, chitin—fungi, glucan and mannan—yeasts)
- Glycocalyx
  - Carbohydrates bonded to proteins and lipids in the plasma membrane
  - Found in animal cells

# The Plasma (Cytoplasmic) Membrane (1 of 3)

## Learning Objective

4-15 Compare and contrast prokaryotic and eukaryotic plasma membranes.

# The Plasma (Cytoplasmic) Membrane (2 of 3)

- Similar in structure to prokaryotic cell membranes
  - Phospholipid bilayer
  - Integral and peripheral proteins
- Differences in structure
  - Sterols—complex lipids
  - Carbohydrates—for attachment and cell-to-cell recognition

# The Plasma (Cytoplasmic) Membrane (3 of 3)

- Similar in function to prokaryotic cell membranes
  - Selective permeability
  - Simple diffusion, facilitated diffusion, osmosis, active transport
- Differences in function
  - **Endocytosis**—phagocytosis and pinocytosis
  - Phagocytosis: pseudopods extend and engulf particles
  - Pinocytosis: membrane folds inward, bringing in fluid and dissolved substances

# Cytoplasm (1 of 2)

## Learning Objective

4-16 Compare and contrast prokaryotic and eukaryotic cytoplasms.

# Cytoplasm (2 of 2)

- **Cytoplasm:** substance inside the plasma and outside the nucleus
- **Cytosol:** fluid portion of cytoplasm
- **Cytoskeleton:** made of microfilaments and intermediate filaments; gives shape and support
- **Cytoplasmic streaming:** movement of the cytoplasm throughout a cell

# Ribosomes (1 of 2)

## Learning Objective

4-17 Compare the structure and function of eukaryotic and prokaryotic ribosomes.

# Ribosomes (2 of 2)

- Sites of protein synthesis
- 80S
  - Consists of the large 60S subunit and the small 40S subunit
  - Membrane-bound: attached to endoplasmic reticulum
  - Free: in cytoplasm
- 70S
  - In chloroplasts and mitochondria

# **Check Your Understanding-7**

## **Check Your Understanding**

- ✓ Identify at least one significant difference between eukaryotic and prokaryotic flagella and cilia, cell walls, plasma membranes, and cytoplasm.

4-13-4-16

- ✓ The antibiotic erythromycin binds with the 50S portion of a ribosome. What effect does this have on a prokaryotic cell? On a eukaryotic cell?

4-17

# Organelles (1 of 3)

## Learning Objectives

4-18 Define **organelle**.

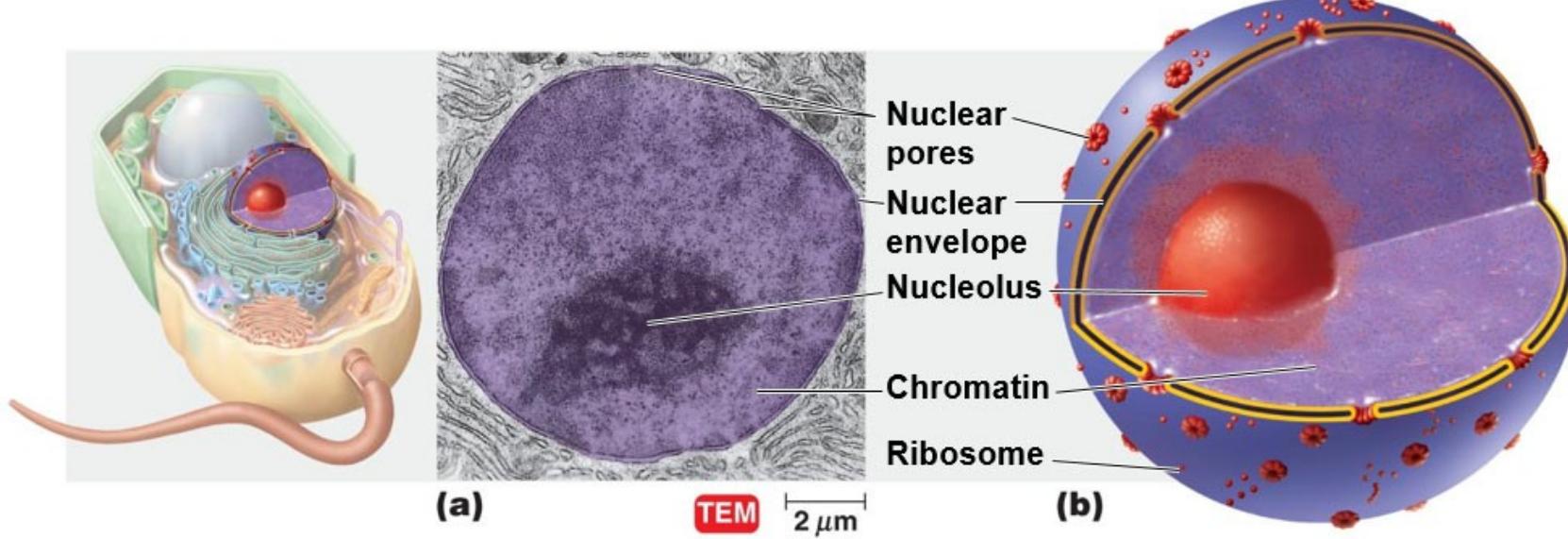
4-19 Describe the functions of the nucleus, endoplasmic reticulum, Golgi complex, lysosomes, vacuoles, mitochondria, chloroplasts, peroxisomes, and centrosomes.

# The Nucleus

- **Nucleus**

- Double membrane structure (**nuclear envelope**) that contains the cell's DNA
- DNA is complexed with **histone** proteins to form **chromatin**
- During mitosis and meiosis, chromatin condenses into **chromosomes**

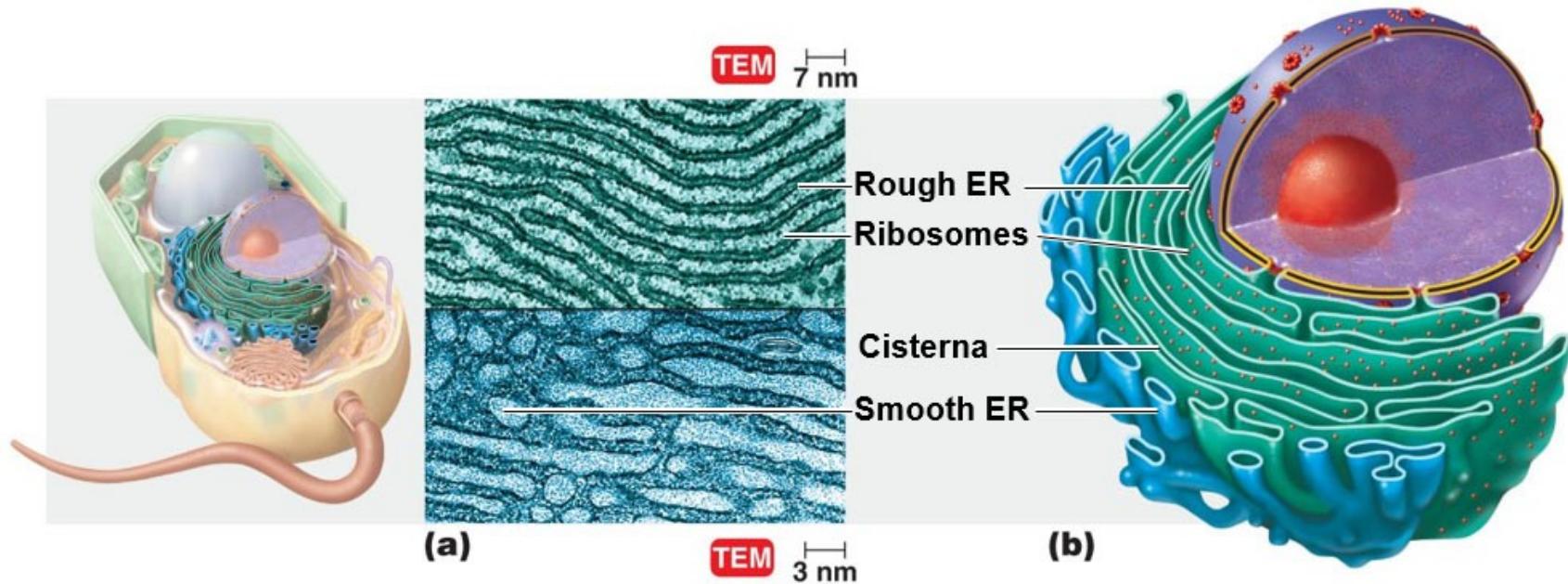
# Figure 4.24 The Eukaryotic Nucleus



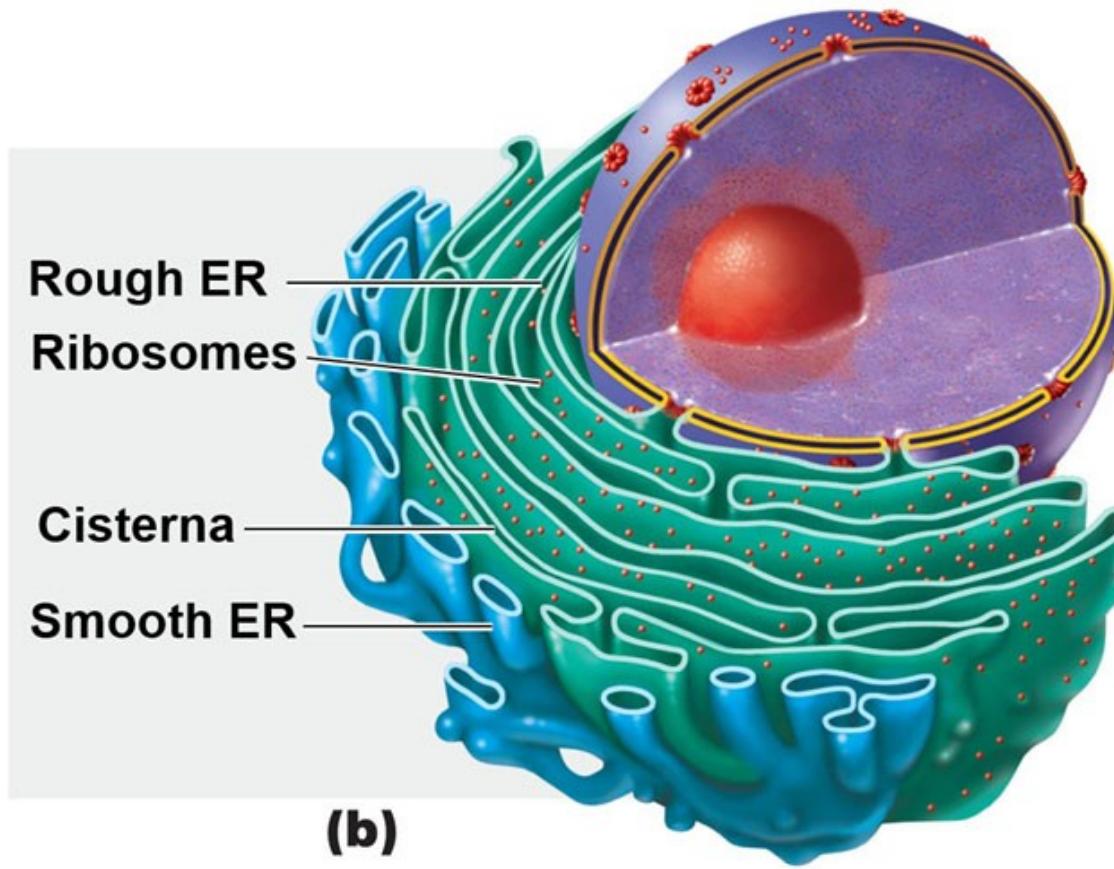
# Endoplasmic Reticulum

- Folded transport network
- **Rough ER:** studded with ribosomes; sites of protein synthesis
- **Smooth ER:** no ribosomes; synthesizes cell membranes, fats, and hormones

# Figure 4.25 Rough Endoplasmic Reticulum and Ribosomes



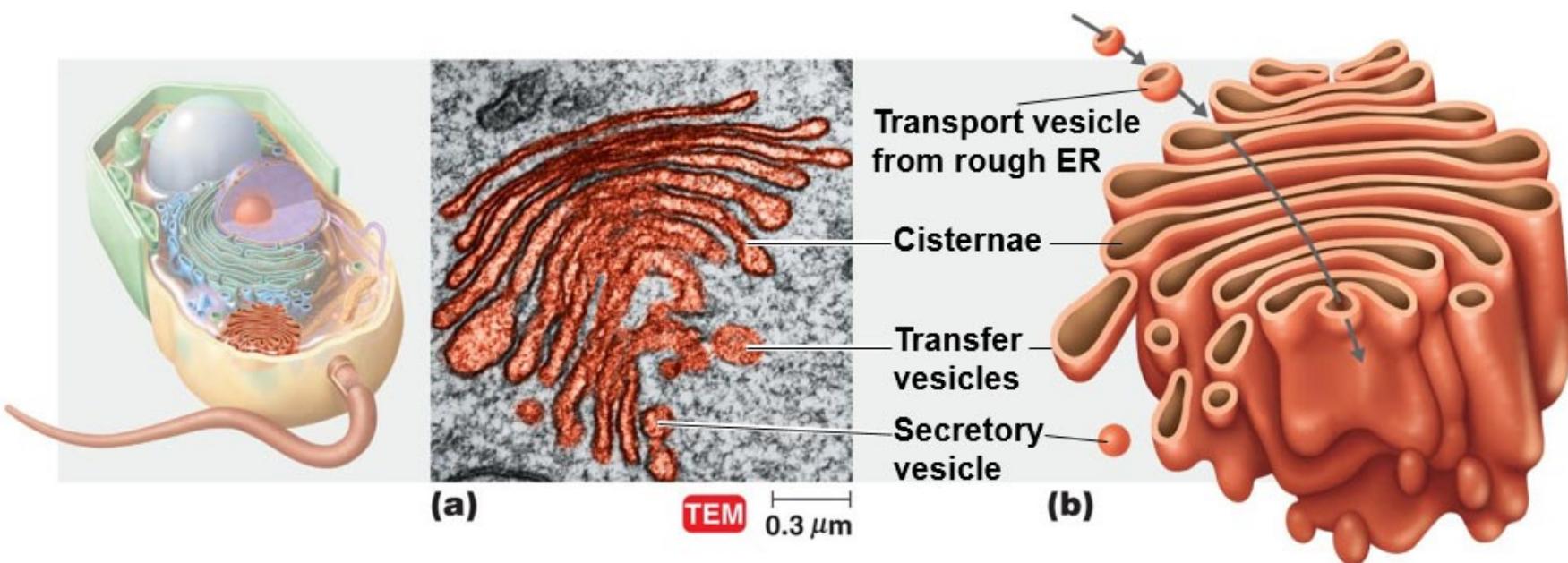
# Figure 4.25b Rough Endoplasmic Reticulum and Ribosomes



# Golgi Complex

- Transport organelle
- Modifies proteins from the ER
- Transports modified proteins via **secretory vesicles** to the plasma membrane

# Figure 4.26 Golgi Complex



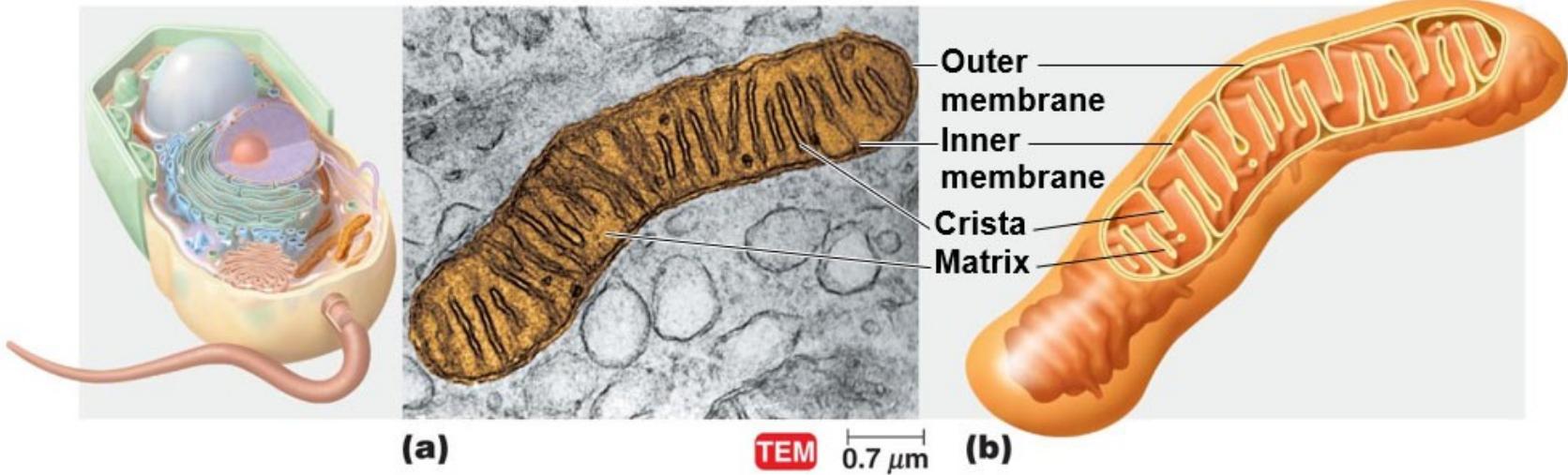
# Mitochondria

- Double membrane
- Contain inner folds (**cristae**) and fluid (**matrix**)
- Involved in cellular respiration (ATP production)

# Organelles (2 of 3)

- **Lysosomes**
  - Vesicles formed in the Golgi complex
  - Contain digestive enzymes
- **Vacuoles**
  - Cavities in the cell formed from the Golgi complex
  - Bring food into cells; provide shape and storage

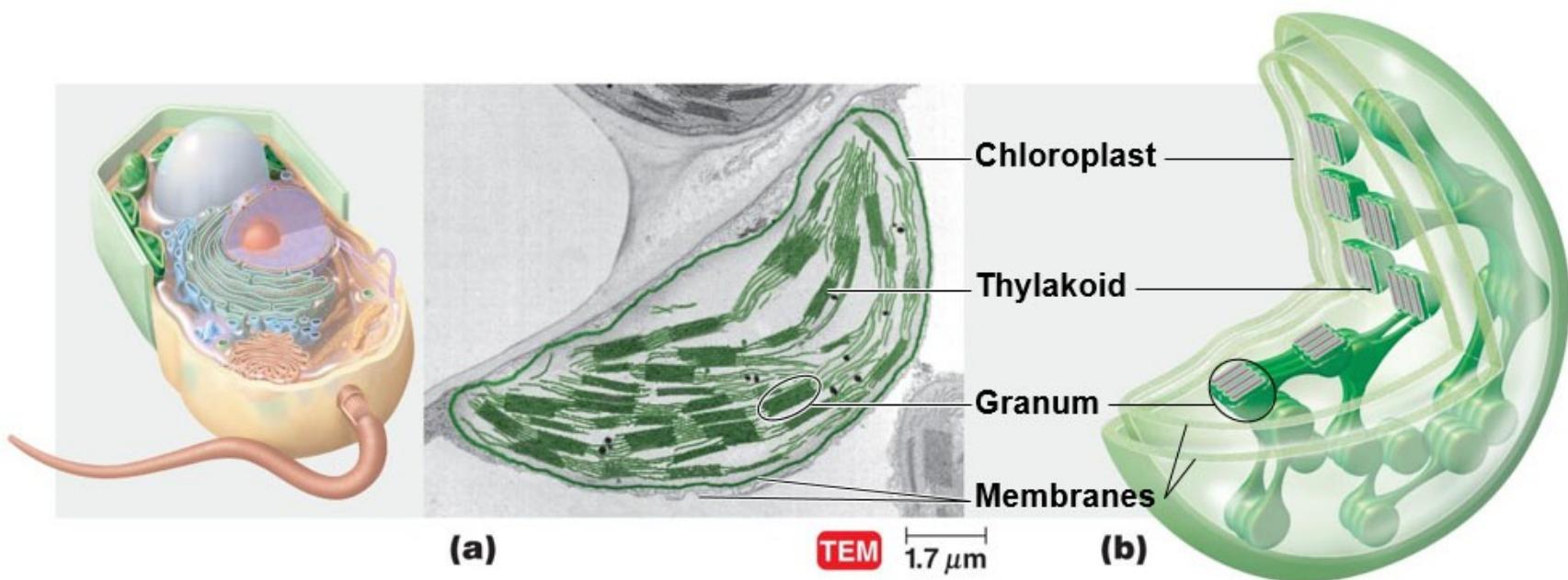
# Figure 4.27 Mitochondria



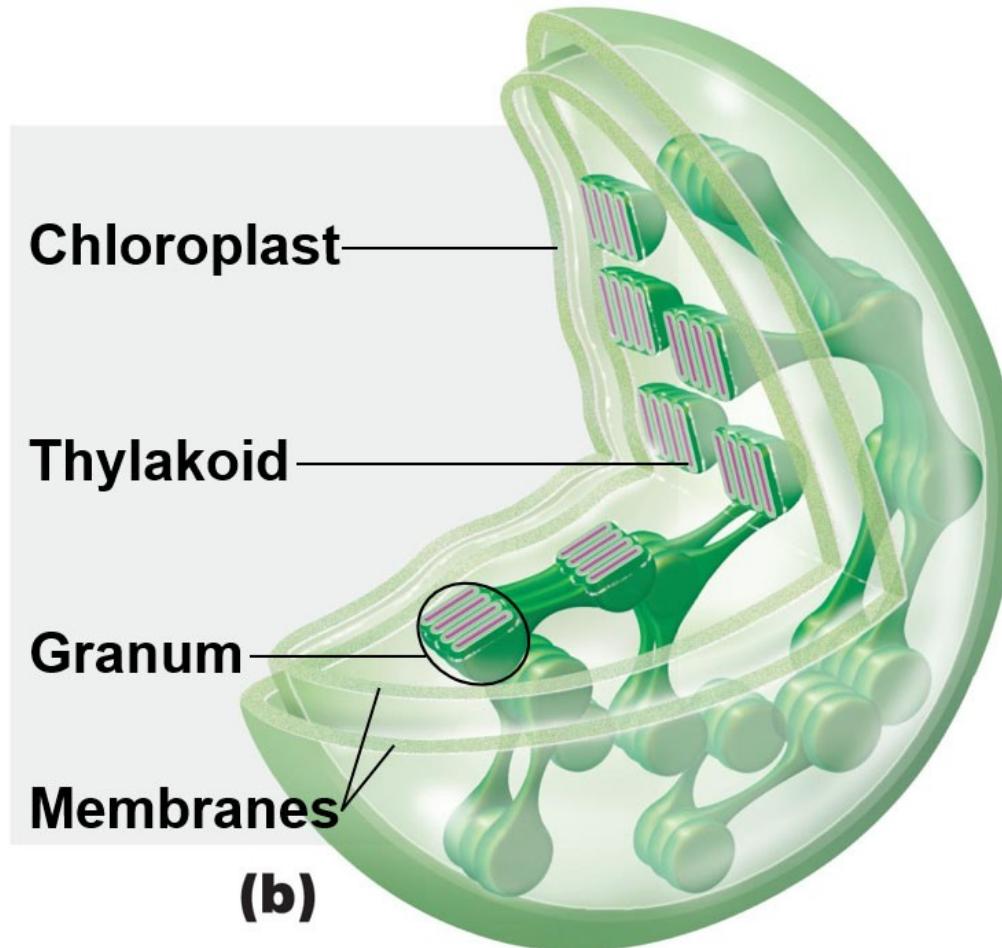
# Chloroplasts

- Locations of photosynthesis
- Contain flattened membranes (**thylakoids**) that contain chlorophyll

# Figure 4.28 Chloroplasts



# Figure 4.28b Chloroplasts



# Organelles (3 of 3)

- **Peroxisomes**

- Oxidize fatty acids; destroy H<sub>2</sub>O<sub>2</sub>

- **Centrosomes**

- Networks of protein fibers and centrioles
  - Form the mitotic spindle; critical role in cell division

# **Check Your Understanding-8**

## **Check Your Understanding**

- ✓ Compare the structure of the nucleus of a eukaryote and the nucleoid of a prokaryote.  
4-18
  
- ✓ How do rough and smooth ER compare structurally and functionally?  
4-19

# The Evolution of Eukaryotes (1 of 3)

## Learning Objective

4-20 Discuss evidence that supports the endosymbiotic theory of eukaryotic evolution.

# The Evolution of Eukaryotes (2 of 3)

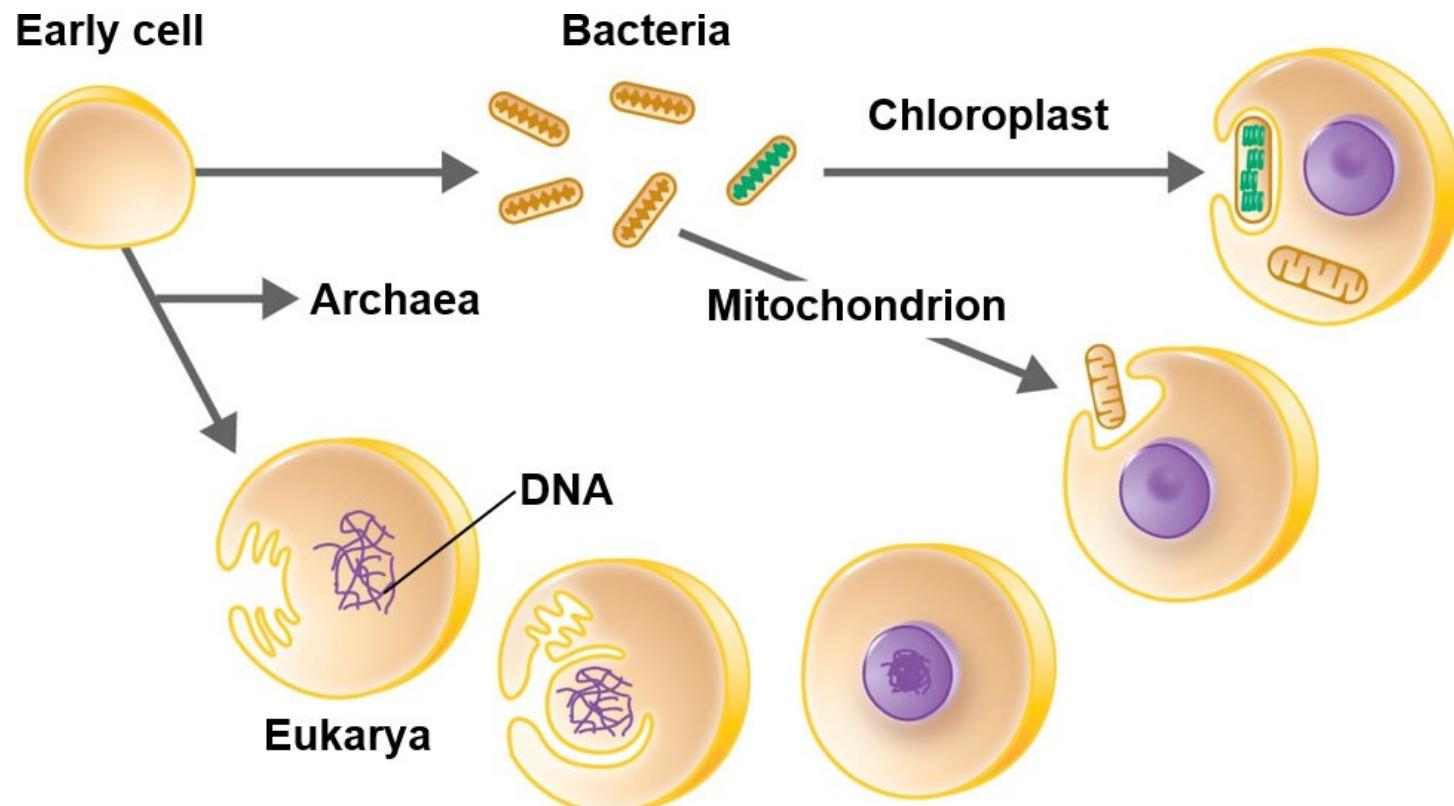
- Life arose as simple organisms 3.5 to 4 billion years ago
- First eukaryotes evolved 2.5 billion years ago

# The Evolution of Eukaryotes (3 of 3)

- **Endosymbiotic theory**

- Larger bacterial cells engulfed smaller bacterial cells, developing the first eukaryotes
- Ingested photosynthetic bacteria became chloroplasts
- Ingested aerobic bacteria became mitochondria

# Figure 10.2 A Model of the Origin of Eukaryotes



# **Check Your Understanding-9**

## **Check Your Understanding**

- ✓ Which three organelles are not associated with the Golgi complex? What does this suggest about their origin?

4-20